

TR 10347
Cop. 1



AD-479296 N

ARMY AVIATION SAFETY

- CRASH INJURY
- CRASHWORTHINESS

Final Report
U. S. ARMY
TRECUM Contract
DA 44 177 TC 624
TREC Technical Report
60 77
AvCIR 70 0 128
30 December 1960

FLIGHT SAFETY FOUNDATION, INC.

PROPERTY OF U. S. ARMY
TRANSPORTATION ENGINEERING COMMAND
RESEARCH REPORT 100 100 100

FLIGHT SAFETY FOUNDATION, INC.
468 Park Avenue South
New York, N. Y.

Jerome Lederer
Managing Director

Merwyn A. Kraft
Research Coordinator

Carl F. Schmidt
Engineering Director

AVIATION CRASH INJURY RESEARCH
A Division of Flight Safety Foundation, Inc.
2871 Sky Harbor Blvd., Phoenix, Arizona

Merwyn A. Kraft
Acting Director

Victor E. Rothe
Manager

John J. Carroll
Chief, Training Branch

Harold F. Roegner
Chief, Investigation Branch

Alfred C. Barnes
Chief, Statistical
Analysis Branch

Gerard M. Bruggink
Chief, Human Factors Branch

William H. Shook
Chief, Experimental Research Branch

Reproduction of the paper, in whole or in part, is
permitted for any purpose of the United States Government.

HEADQUARTERS
U. S. ARMY TRANSPORTATION RESEARCH COMMAND
TRANSPORTATION CORPS
Fort Eustis, Virginia

TCREC-ADR 9R95-20-001-01

SUBJECT: Army Aviation Safety Report

TO: See Distribution List

1. The inclosed TREC Technical Report 60 77, "Army Aviation Safety", was prepared by Aviation Crash Injury Research, a division of Flight Safety Foundation, Inc., under the provisions of Contract DA 44-177-TC-624. Conclusions and recommendations contained in the report are concurred in by this Command.


2. Contents of this report are a compilation of all significant efforts and findings produced by the contractor during the term of the contract. Reports published prior to this report and referenced therein, are currently being reviewed by the U. S. Army Transportation Materiel Command. Upon completion of this review, appropriate action will be taken by cognizant agencies.

3. Under the terms of a new contract with the Flight Safety Foundation, Contract DA 44-177-TC-707, aviation crash injury research work has been expanded to include dynamic crash test experiments and investigation of post-crash fire hazards. Results of this research will be incorporated in applicable military specifications and will be used as a basis for the development of improved aircraft design criteria.

4. We would appreciate receiving your comments, if any, relative to this report. Correspondence should be addressed to Commanding Officer, U. S. Army Transportation Research Command, Fort Eustis, Virginia, marked for the attention of the Research Analysis Division.

FOR THE COMMANDER.

1 Incl
a/s


EARL A. WIRTH
CWO-4
Adjutant



TREC Technical Report 60-77
AvCIR 70-O-128

ARMY AVIATION SAFETY

with reference

to

CRASH INJURY AND CRASHWORTHINESS

PROGRAMS

(Revised TR 70-O-128-21)

FINAL REPORT

under

U. S. ARMY
TRANSPORTATION RESEARCH COMMAND
Contract DA-44-177-TC-624

16 September 1959 - 15 December 1960

FLIGHT SAFETY FOUNDATION, INC.
468 Park Avenue South
New York, N. Y.

30 December 1960

All publications of the AvCIR Division, FSF, are prepared under the supervision of a Technical Support Branch, Robert E. Klemme, Chief.



TABLE OF CONTENTS

	<u>Page No.</u>
FOREWORD	i
ACKNOWLEDGEMENTS	iii
BACKGROUND	v
AvCIR ORGANIZATION AND PERSONNEL	vii
Operating Branches	viii
(1) Accident Investigation Branch	viii
(2) Statistical Analysis Branch	viii
(3) Training Branch	ix
(4) Human Factors Branch	x
(5) Experimental Research Branch	x
Technical Support	xi
Administration	xiii
STATEMENT OF WORK	xv
SUMMARY	xvii
SECTION	
I TRAINING IN CRASH INJURY INVESTIGATION	1
II FIELD ACCIDENT INVESTIGATION	5
U. S. Army HU-1A, East St. Louis, Illinois	8
U. S. Army U-1A, Fort Carson, Colorado	12
U. S. Army H-21C, Big Meadows, Virginia	16
U. S. Army HU-1A, Fort Carson, Colorado	20

SECTION

II FIELD ACCIDENT INVESTIGATION (Cont'd.)

U. S. Army HU-1A, Fort Bragg, N. C.	23
U. S. Army L-21A, Starkville, Miss.	26
U. S. Army YH-41, Phoenix, Ariz.	28
U. S. Army H-13G, Ft. Devens, Mass.	29
U. S. Army National Guard H-23C, Phoenix, Arizona	30

III CRASH INJURY EVALUATION 31

U. S. Army AO-1BF Mohawk Mock-up, Bethpage, Long Island, New York.	33
U. S. Army YHC-1B Chinook Mock-up, Morton, Pennsylvania	36
U. S. Army AC-1 DeHavilland Caribou, Ft. Rucker, Alabama	38
U. S. Army HU-1D, Bell Iroquois Helicopter Mock-up, Ft. Worth, Texas	40
Summary Evaluation, U. S. Army HU-1A Bell Helicopter	42

IV CRASH SURVIVAL DESIGN CRITERIA 49

V QUANTITATIVE ANALYSIS OF ACCIDENT DATA . . . 53

VI EXPERIMENTAL RESEARCH (CRASH TESTING) 59

Preliminary Considerations	60
H-25 Helicopter Drop Test	62
L-19 Drop Test	82



Page No.

SECTION

VII	DYNAMIC TESTING OF SAFETY DEVICES	85
VIII	MISCELLANEOUS CRASH INJURY RESEARCH	87
	Crash Injury Bulletin - Improper Instruction in the Use of Safety Belts in H-21 Helicopter Manual	88
	Crash Injury Bulletin - Part I - Attachment of Seat Belts in the HU-1A Helicopter Part II - Stowage of Equipment under Troop Seats . .	90
	Impact Survival in Military Rotary Wing Aircraft	92
	Medical Officer's Role in the Crash Injury Prevention Program	93
	The Mechanism of Aviation Crash Injuries	94
	Impact Survival in Air Transport Accidents	95

APPENDIX

A	FIELD INVESTIGATION - CIVILIAN ACCIDENTS . . .	97
B	PUBLICATIONS LIST	109



FOREWORD

As of 16 September 1959, Flight Safety Foundation, Inc. (FSF), a non-profit corporation in New York City, entered into a contract with the U. S. Army Transportation Research Command (TRECOM), No. DA-44-177-TC-624, for the period through 15 September 1960. The contract was to be executed largely by Aviation Crash Injury Research (AvCIR), a Division of FSF in Phoenix, Arizona. Its objective was to "conduct research generally in fields related to Army Aviation Safety, with particular reference to Crash Injury and Crashworthiness Programs."

Initial funding in the amount of \$140,000 was provided by TRECOM and the Office of the Surgeon General, Department of the Army. Later, this was increased by \$10,000 to cover the cost of training approximately 40 military students in the principles and special techniques of aircraft crash injury investigation.

Agreement also was reached upon another increase in the amount of \$60,000 to permit study of the causes of Army aviation accidents under the general heading of "Measures For The Improvement of Durability and Reliability in Army Aviation." This was conducted through a sub-contract between FSF and Operations Research, Incorporated (ORI) of Silver Spring, Maryland. (The report covering this special contract commitment is being submitted separately.)

A final modification in funding provided an additional \$100,000 to support a full-scale crash test of an H-25 Piasecki helicopter; also, in order

to allow time for completion of this latter additional task under the existing contract, the period of the contract was extended through 15 December 1960.

This report covers all work performed and completed under U. S. Army TRECOM Contract DA-44-177-TC-624, as modified, for the entire period of 16 September 1959 to 15 December 1960, the ORI sub-contract excepted. It also covers related activities carried on through financial support from other than Army sources. These are included because they augment the work performed under the TRECOM contract and have direct value and applicability to Army aircraft crash injury and crashworthiness problems (see Section V and Appendix A).



ACKNOWLEDGEMENTS

The Flight Safety Foundation expresses its appreciation to the Office of the Surgeon General, Department of the Army, for the very valuable services of William R. Knowles, Captain, MSC, who completed a four-year assignment with Aviation Crash Injury Research on 10 June 1960. In recognition of his contribution, Captain Knowles received an FSF Award of Merit together with a Special Citation from the AvCIR Division.

Appreciation also is expressed for the subsequent services of James D. Davenport, Lt. Col., MSC, now assigned to the project.

Grateful acknowledgement also goes to the Commanding General, Army Electronic Proving Ground at Fort Huachuca. Their continued cooperation by providing representative Army aircraft for crash injury evaluation by military accident investigators in training has been most helpful; they also provided the H-21 helicopter with crew to execute the drop test of an L-19 aircraft.

The very successful full-scale crash test of an H-25 helicopter virtually would have been impossible without the cooperation and support given by the Command Officers and the staff of Williams Air Force Base. Not only did they provide a base for operations but also the sites for both preliminary and final drops, together with fire protection and ambulance support.

Field investigation of simulated aircraft accidents is conducted at Papago Park National Guard Base. This has been made possible because of the sincere interest and fine cooperation received from the Army National Guard personnel.

Finally, acknowledgement goes to I. Irving Pinkel, Chief, Fluid Systems Division, Lewis Flight Propulsion Laboratory, National Aeronautics and Space Administration, Cleveland, Ohio for his guidance in the design and execution of the H-25 crash test and for his counsel in formulating a long-range experimental research program; to personnel of Photo-Sonics, Inc. of Burbank, California for voluntary, unsolicited photographic coverage of the crash test with a newly-developed high-speed 35 mm. camera; and to Derwyn M. Severy, Research Engineer, ITTE, University of California at Los Angeles for similar coverage with a 70 mm. high-speed camera. The Photo-Sonics photography is used in a documentary film; sequence photos from the 70 mm. film are reproduced in Section VI.



BACKGROUND

Aviation Crash Injury Research (AvCIR), a Division of Flight Safety Foundation, Inc. (FSF), has for many years engaged in aircraft accident research involving the relationships between injury, force, and aircraft structure. The results of this research have contributed to increased crash safety design in aircraft which, in turn, has led to an increased survival rate in aircraft accidents. Much still remains to be done in this area, however.

Aviation crash injury research formally was initiated in 1942 at Cornell University Medical College under the direction of Mr. Hugh DeHaven. In 1957, the AvCIR project was moved from New York City to Phoenix, Arizona, and in April 1959, was transferred from Cornell University to the Flight Safety Foundation.

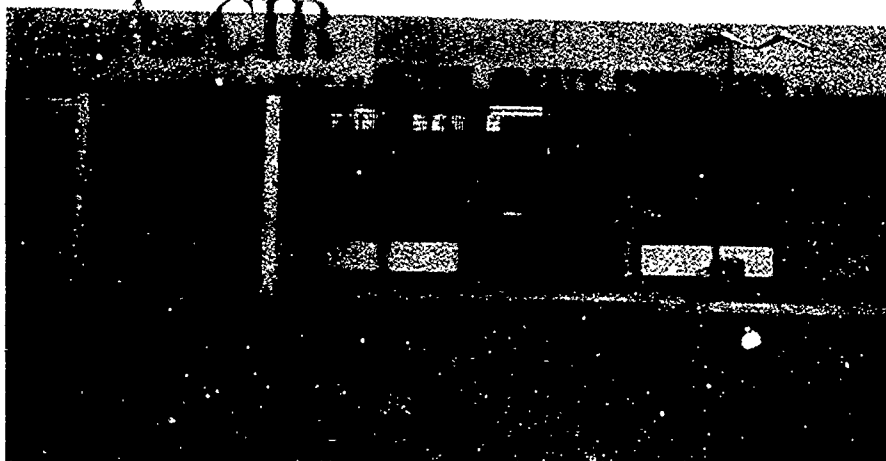
Direct financial support for aviation crash injury research has been provided over various periods by the Army, the Navy, the Air Force, the National Institutes of Health of the U. S. Public Health Service, major foreign and domestic airlines, aircraft and equipment manufacturers, and various aviation groups such as the Air Line Pilots Association and the Aircraft Owners & Pilots Association. Indirect support is provided by many experts in the aeronautical and medical fields who serve as consultants, and also by agencies such as the Armed Forces Institute of Pathology, the Civil Aeronautics Board, the Federal Aviation Agency, state aviation groups, and state police forces.

The research conducted by AvCIR involves aircraft of all types - fixed wing as well as rotary wing, civilian as well as military, transport as well as light plane. Although the various contracts and grants which support this research generally are written in a manner to cover specific work involving certain aircraft types, the research findings are of such a broad nature that they are applicable to most different aircraft types. For example, most Army aircraft have their civilian counterpart. The findings under the Army contract, therefore, are applicable to light private aircraft and are used in studies supported by a grant from the National Institutes of Health. The reverse also holds true. Likewise, knowledge gained from investigation and study of survivability in transport type aircraft accidents is translated into both military and private plane applications. Consequently, the collective research of the entire project has broad, direct value to all supporting and sponsoring agencies.



AvCIR ORGANIZATION AND PERSONNEL

In view of the expanded and intensified activity called for under the TRECOM contract, as well as under the earlier NIH grant, a broad program of reorganization was initiated early in the contract period. This included expansion of staff in the field of accident investigation and of technical staff in areas of statistical analysis and experimental research. It also included relocation into new, modern office quarters.



Reorganization was completed during the contract period with the establishment of five (5) operating branches: (1) Accident Investigation, (2) Statistical Analysis, (3) Training, (4) Human Factors, and (5) Experimental Research.

OPERATING BRANCHES

(1) The Accident Investigation Branch conducts on-the-scene investigations of all types of aircraft accidents.

The military accidents investigated presently are limited to Army aircraft which fall into both the light plane and helicopter categories. Civilian accidents investigated include both transport and private aircraft. When investigating civilian accidents, AvCIR personnel customarily serve as observers with the CAB or FAA investigating teams.

In addition to on-the-scene accident investigations, this branch also conducts evaluations of preliminary designs, mock-ups, prototype, and operational aircraft from a crashworthiness or crash injury point of view. Again, either military or civilian aircraft may be involved.

As a result of investigations and evaluations, reports on findings are prepared for distribution to interested agencies; discussions also are held with aircraft and equipment designers and manufacturers. These reports and discussions provide a basis for new, improved designs and modifications in existing designs as they relate to safety. The information compiled by this branch also becomes a part of the mass data accumulated for statistical studies.

(2) The Statistical Analysis Branch collects, codes, and analyzes mass aircraft accident data. Data currently is being received on special AvCIR accident and medical report forms from the FAA, the CAB, the U. S. Army, state aviation groups, and state police forces.



The Collection and Coding Section performs machine data processing of aircraft accident and injury information, including the coding of accident and medical reports, IBM card processing, and case filing.

The Statistical Section analyzes the mass data for the purpose of determining injury causal factors out of the complex and otherwise indeterminate events. Results of these analyses are published in statistical reports along with recommendations for corrective action regarding design features which repeatedly cause injuries.

The Trend Analysis Section has as its principal objective the surveillance of measurable trends of a general nature in, for example, accident rates, injury severity rates, installation and utilization of safety equipment, and structural and design features related to injuries.

The Medical Section conducts special studies dealing with the frequency and pattern of injuries experienced in specific areas of the body and corresponding causes thereof.

(3) The Training Branch maintains and operates the Crash Injury Investigator's School. It conducts 2-week training courses for military and civilian design engineers, flight surgeons, aviation safety officers, and other interested persons, including representatives of foreign countries. The operation of this branch permits direct dissemination and interchange of the data and findings of AvCIR and other agencies as a result of research and investigations, thus broadening the probability of improved crash safety design. This activity also results in a noticeably higher quality of

subsequent accident reporting by those who have received this training.

(4) The Human Factors Branch is responsible basically for study of the correlation of injuries to causative agents in aircraft accidents with the emphasis on occupant restraint, occupant environment, protective equipment, and emergency evacuation. It is here where AvCIR is able to exploit the many types of data and information obtained or fed into the organization from many sources. Typical of recent subjects covered are: "Impact Survival in Air Transport Accidents"; "The Mechanism of Aviation Crash Injuries"; and "The Medical Officer's Role in the Crash Injury Prevention Program."

(5) The Experimental Research Branch is responsible for the design and execution of experiments which will provide increased knowledge of the dynamic behavior of aircraft and their components under actual crash conditions. The experiments include crash testing of full-scale aircraft under fully instrumented, controlled conditions and the dynamic testing of aircraft components.

The design of each experiment is built upon the problems brought into focus by the other elements of the organization, wherein the indications are that answers to certain key questions can be found only by simulating certain crash situations under dynamic conditions.

Two full-scale crash tests and a number of component tests have been conducted since this branch was established.



TECHNICAL SUPPORT

The AvCIR program has not yet expanded to a point that will permit full-time utilization of all applicable technical and professional skills; consequently, advantageous use has been made of consultants on a part-time basis. In fact, the capability brought to the program in this manner under the current contract undoubtedly has exceeded that which could have been obtainable on a full-time staff basis.

Consultants

For data collection, data processing, and statistical methods and procedures:

Lee W. Gregg, Ph. D., Associate Professor of Psychology,
Carnegie Institute of Technology, Pittsburgh, Pa.

For the Experimental Research Program (full-scale crash tests and dynamic testing development):

James W. Turnbow, Ph. D., Professor of Engineering Science,
Arizona State University, Tempe, Arizona.

Richard Ditsworth, Ph. D., Associate Professor, Engineering
Science, Arizona State University.

John O. Moore, former Director, Automotive Crash Injury Research
of Cornell University, New York.

Technical Supervisory Committee

Under terms of the contract, the following serve in an advisory capacity:

Representing TRECOM - Francis P. McCourt, Chief
Research & Analysis Division
Aviation Directorate
U. S. Army Transportation
Research Command

Representing FSF - Capt. Carl M. Christenson
Assistant Vice President
Flight Operations
United Air Lines, Inc.

Mr. Otto Koppen
Professor, Aeronautical Engineering
Massachusetts Institute of Technology

Col. Frank M. Townsend, USAF (MC)
Director, Armed Forces Institute
of Pathology

Dr. T. F. Walkowicz
Associate of Laurance S. Rockefeller



ADMINISTRATION

Jerome Lederer, Managing Director of the Flight Safety Foundation, is responsible for all activities of FSF;

Merwyn A. Kraft, FSF Research Coordinator, has direct, overall responsibility for the AvCIR Division; he also serves as FSF Security Officer;

Carl F. Schmidt, FSF Engineering Director, holds the responsibility as Engineering Advisor to AvCIR;

Murray Sargent, Jr., FSF General Counsel and Treasurer, handles all legal and financial matters; and

Victor E. Rothe, Manager, AvCIR Division, provides all operational, technical, and administrative supervision in Phoenix.



STATEMENT OF WORK

The Contract called for the Flight Safety Foundation to carry on the following activities:

- (1) Provide training courses in crash injury investigation, on a continuing basis, to include an Aircraft Accident Investigation School to be conducted for a 2-week period, four (4) times a year, with an attendance of approximately 10 students per term, to be nominated by the Contracting Officer* (see Section I);
- (2) Make crash injury reports of survivable aircraft accidents and prepare a statistical, qualitative, and quantitative analysis of these reports (see Section II - Investigation and Section V - Analysis);
- (3) Prepare an illustrated crashworthiness design report, review and submit recommended revisions to existing Military Specifications, and study general design criteria for crash safety (see Section IV);
- (4) Conduct crashworthiness evaluations of model specifications, proposed manufacturer's designs, mock-ups, and current Army aircraft and report findings (see Section III);
- (5) Conduct crash tests of available representative types of aircraft furnished by the Contracting Officer for crash injury research,

* Note: A fifth course later was authorized.

studies, and investigations (see Section VI);

- (6) Test to destruction safety devices, such as shoulder harness, safety belts, seats, etc., to determine maximum loading, method of failure, effects of sequency of failure, etc., and report deficiencies and make recommendations of possible improvements to such safety devices (see Section VII); and
- (7) Conduct specific related tasks as assigned by the Contracting Officer, or as recommended by the Contractor and approved by the Contracting Officer (see Section VIII).



SUMMARY

During the fifteen-month period of TRECOM contract No. DA-44-177-TC-624, there were accomplishments in all areas of activity called for under the Statement of Work.

1. Fifty-four (54) military students were trained in aviation crash injury investigation in five (5) 2-week courses. Of these, thirty-two (32) were flight surgeons and aviation medical officers, fifteen (15) were aviation safety officers and Army-employed civilian safety personnel, and seven (7) represented research, development, and procurement activities.
2. A total of eight (8) U. S. Army aircraft accidents were investigated in the field; reports contain recommendations such as
a) increasing the integrity of the side and rear roof support structure of the HU-1A Bell Iroquois Helicopter; b) increasing the strength of seats and tie-down systems both for pilots and passengers; c) whenever practical, the attachment of all restraining devices to the basic structure of the aircraft; and d) increasing the tie-down strength requirement for the engine and transmission of the HU-1A Bell aircraft.
3. Crash Injury and Crashworthiness Evaluations were conducted on two (2) Army aircraft, the AC-1DH De Havilland Caribou and HU-1A Bell Iroquois helicopter, and on three (3) Army aircraft

mock-ups, AO-1BF Mohawk, YHC-1B Chinook, and HU-1D Bell helicopter. Desirable features such as a cockpit stressed for 40G and a 40G pilot seat were pointed out; specific corrective measures for certain undesirable features are suggested relating to flight control areas, main cabin, airframe, and certain military specifications. It also is noted that several of the changes suggested for the HU-1A Bell Iroquois helicopter have been incorporated in the HU-1B production models, particularly the suggestion as to increasing the integrity of side structure support.

4. Agreement was reached on an outline for a new Handbook of Crash Survival Design Criteria for the ultimate guidance of engineers, specification writers, and manufacturers.
5. A comprehensive review and re-evaluation of aircraft and accident data collection, processing, and analysis methods and procedures, including development of new, simplified accident report forms, was completed; also a number of special statistical studies dealing with accident variables as they relate to type and degree of injury, were carried forward.
6. Plans were developed for a long-range experimental research program to include full-scale crash tests and the dynamic testing of accessories and components; the program was initiated with a full-scale drop test of an H-25 helicopter from a moving crane and a drop test of an L-19 aircraft from an H-21 helicopter.



Comprehensive electronic and photographic recording provide data on the true dynamics of aircraft accidents and support the need for continued experimental research of this character.

7. Through Crash Injury Bulletins and presentations before medical and professional groups, detailed information was presented on specific operational and design features that relate to crash injury and crashworthiness and which lend themselves to corrective control by military authorities.



SECTION I

TRAINING IN CRASH INJURY INVESTIGATION

This recognizes the urgent need to develop a group of key military personnel with specialized skills for the scientific investigation of aircraft accidents as they effect injury and survival. Only from this can come the more complete and accurate information required by analysts and designers in the determination of causes of injury and, subsequently, in development of corrective measures.



SECTION I

During the contract period, five (5) 2-week courses were held in which fifty-four (54) military students were trained. Of these, thirty-two (32) were flight surgeons and aviation medical officers, fifteen (15) were aviation safety officers and Army-employed civilian safety personnel, and seven (7) represented research, development, and procurement activities. Assignments were handled through the Research Contracting Officer.

Upon completion of this course, graduates are considered qualified to investigate and analyze aircraft accidents relative to: (1) finding specific causes of minor, serious, and fatal injuries sustained in fixed-wing, rotary-wing, and transport aircraft crashes; (2) determining reasons for survival and non-survival; (3) evaluating the effect of crash safety design both structural and environmental; (4) evaluating the over-all crashworthiness of aircraft in relation to impact severity; (5) recommending new engineering design criteria to prevent serious or fatal injuries from occurring in future survivable-type accidents. This is evidenced by the much higher quality of crash injury reports received by AvCIR from Army field investigations when they are handled by those with this training background.

Of the total of six., (60) hours comprising the course, one-half of the time is devoted to the investigation phases, including eight (8) hours of field investigation at simulated accident sites and four (4) hours of crash-worthiness evaluation and analysis of actual aircraft. Further details are given in a revised Program of Instruction prepared and published under this contract.



SECTION I

The following table summarizes military attendance:

<u>Dates</u>	<u>Aviation</u>	<u>Military Medical</u>	<u>MSC & R&D</u>	<u>Civilian Government</u>
30 Nov. - 11 Dec. 1959	3	6	1	-
8 Feb. - 19 Feb. 1960	-	8	2	-
28 Mar. - 8 April 1960	1	5	1	1
16 May - 27 May 1960	6	6	3	-
31 Oct. - 11 Nov. 1960	<u>4</u>	<u>7</u>	<u>-</u>	<u>-</u>
Totals:	14	32	7	1

A typical group of fifteen (15) military students is illustrated below:



SECTION I

All instruction is handled by AvCIR staff; however, this customarily is supplemented by specialized, technical presentations by one or two guest lecturers at each course. The following contributed greatly to the success of these courses during this period:

Col. Frank Townsend, USAF (MC), Director, Armed Forces
Institute of Pathology, Washington, D. C.

Major F. W. Lovell, USAF (MC), Chief, Aerospace Pathology
Branch, AFIP, Washington, D. C.

Major Edward H. Johnston, USAF (MC), Chief, Forensic
Pathology Branch, AFIP, Washington, D. C.

Capt. Harrison McMichael, USAF (MC), AFIP

Capt. W. Harley Davidson, USAF (MC), Chief, Aerospace
Branch, AFIP, Washington, D. C.

Col. James F. Wells, Director, USABAAR, Ft. Rucker,
Alabama

Capt. Quitman W. Jones, Human Factors Section, USABAAR,
Ft. Rucker, Alabama

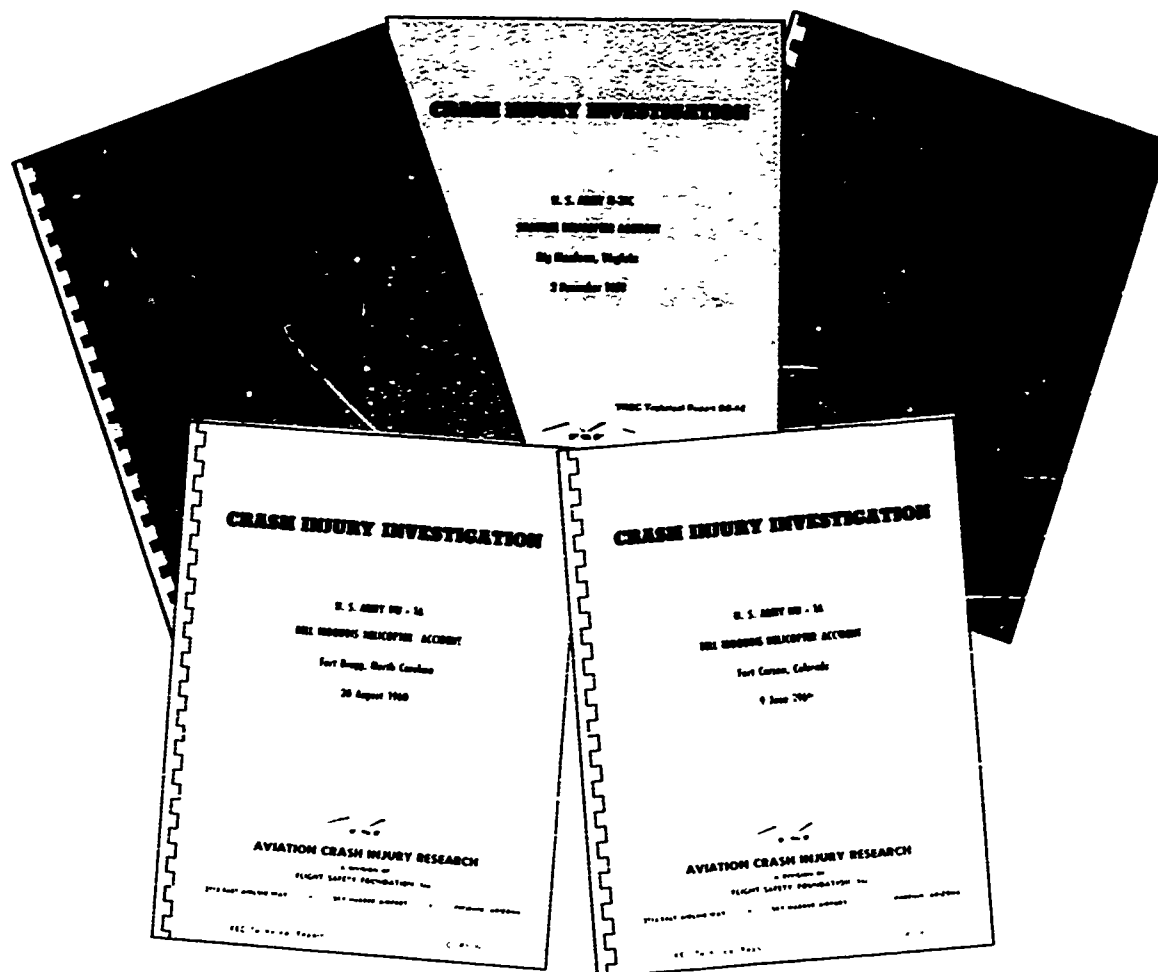
Col. John P. Stapp, USAF Aerospace Medical Center (ATC),
Brooks Air Force Base, Texas

Mr. William Littlewood, Vice-President, American Airlines
and Vice-Chairman, Industry Advisory Committee of
Flight Safety Foundation



FIELD ACCIDENT INVESTIGATION

Post-crash investigation of aircraft accidents provides valuable information on engineering and medical factors directly related to survivability and, in turn, provides support for improvements in crash safety design.



SECTION II

A total of eight (8) U. S. Army aircraft accidents - six (6) rotary wing and two (2) fixed wing - were investigated in the field under this contract.

Three (3) final reports were completed and distributed in accordance with instructions by TRECOM; one of these covered an accident investigated under a prior contract with the Office of Naval Research. One (1) report was limited to draft form only; the additional five (5) reports are being completed and will be distributed under later instructions.

A summary statement covering all field investigations and reports is given in the pages that follow.

Reference also should be made to Appendix A wherein a summary is given for nine (9) civilian aircraft accidents investigated. While these were handled outside the framework of the TRECOM contract, they have either direct or indirect implications of interest and value to the Army.

In these latter cases, findings are submitted to and discussed with aircraft and equipment manufacturers and with the operators involved. Accumulated information then is consolidated into design notes, bulletins, or other appropriate forms for the guidance of design engineers, official agencies, medical groups, and others for their use in attaining greater crash safety.

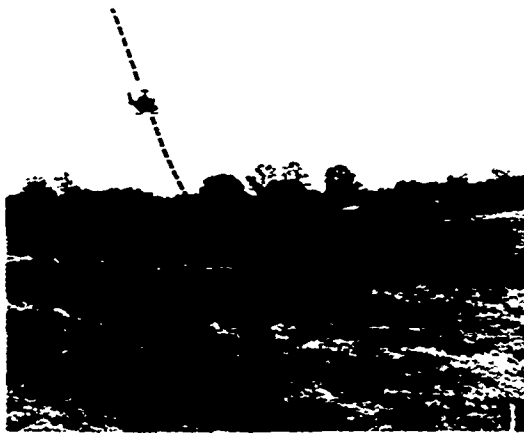


SECTION II

U. S. Army HU-1A Bell Iroquois Helicopter Accident East St. Louis, Illinois	TREC Report CRD 2859	AvCIR-10-PR-110 January 1960
U. S. Army U-1A DeHavilland Otter Accident Ft. Carson, Colorado	TREC Report CRD 2459	AvCIR-9-PR-104 February 1960
U. S. Army H-21C Shawnee Helicopter Accident Big Meadows, Virginia	TREC Technical Report 60-14	AvCIR-11-PR-112 February 1960
U. S. Army HU-1A Bell Iroquois Helicopter Accident Ft. Carson, Colorado	TREC Technical Report 60-72	AvCIR-12-PR-122 December 1960
U. S. Army HU-1A Bell Iroquois Helicopter Accident Ft. Bragg, North Carolina	TREC Technical Report 60-71	AvCIR-13-PR-123 December 1960
U. S. Army L-21A Piper Super Cub Accident Starkville, Mississippi	-	(Draft form only)
U. S. Army YH-41 Cessna Helicopter Accident Phoenix, Arizona	-	Memorandum report only
U. S. Army H-13G Bell Helicopter Accident Ft. Devens Army Airfield Ft. Devens, Massachusetts	-	Memorandum report only
U. S. Army National Guard H-23C Hiller Helicopter Accident Phoenix, Arizona	-	Being reported under TRECOM Contract TC-707

SECTION II

U. S. ARMY HU-1A BELL IROQUOIS HELICOPTER ACCIDENT EAST ST. LOUIS, ILLINOIS 21 OCTOBER 1959



A U. S. Army HU-1A Bell Iroquois helicopter, engaged in a demonstration and recruiting mission, crashed while on a flight before a group of students and instructors at Parks Air College Airfield, East St. Louis, Illinois, at 1055 hours on 21 October 1959.



The helicopter had completed a high-speed run parallel to and in front of the spectators when the pilot initiated a cyclic climb to approximately 500 feet above the terrain in preparation for an autorotative descent. At this altitude he made an 180-degree turn and with a forward velocity of 30-40 knots, he reduced power, lowering the nose of the aircraft and entered autorotation. Immediately after entering the maneuver, the pilot, noting an unusually





SECTION II

high rate of descent at a point estimated to have been 200 feet above the terrain, leveled the aircraft and applied full power and collective pitch, but could not decrease the high rate of vertical descent. He continued application of power and pitch and succeeded in partially reducing the high "sink" rate just prior to the crash.

Still in a level attitude with an estimated flight path velocity of 40-50 knots, the aircraft crashed in a flat, heavily sodded open area on the college airfield.

At impact the tail boom began shearing loose and tore completely free as the aircraft rebounded into the air. The aircraft struck the ground two more times finally coming to rest approximately 420 feet from the point of initial impact. During this sequence, the engine tore free from its mounts and rolled to the right of the crash path.

Cargo and cabin doors were torn free and the main transmission, mast, and rotary assembly tore free during the rolling of the aircraft near the end



SECTION II

of the crash path. When the aircraft came to rest inverted, it was found that the roof had failed in compression collapsing against the seat backs of the pilot's and copilot's seats.

The pilot and crew chief, the only occupants aboard the aircraft, survived the accident. The pilot sustained a serious lumbar spinal injury, and the crew chief sustained only minor injuries. Both crew members were wearing safety belts but not shoulder harnesses or crash helmets.



The investigation on 23-24 October 1959 revealed that the seat and cushion contributed to amplification of the crash force imposed on the pilot causing the spinal injury. It was revealed that the structure supporting the roof failed under relatively moderate crash forces per-

mitting the roof structure to crush into the cockpit and cabin under survivable crash force conditions.

The investigation found also that the skids and cross tubes absorbed a considerable amount of energy during the crash, that the doors broke off and allowed large exits for escape, and that the fuel cells are located in an area not highly subject to impact damage.





SECTION II

As a result of these findings, it was recommended: (1) that immediate steps be taken toward increasing the integrity of the roof supporting structure of this helicopter, and (2) that seats utilized in this aircraft should be so designed as to offer occupants a higher degree of energy absorption.

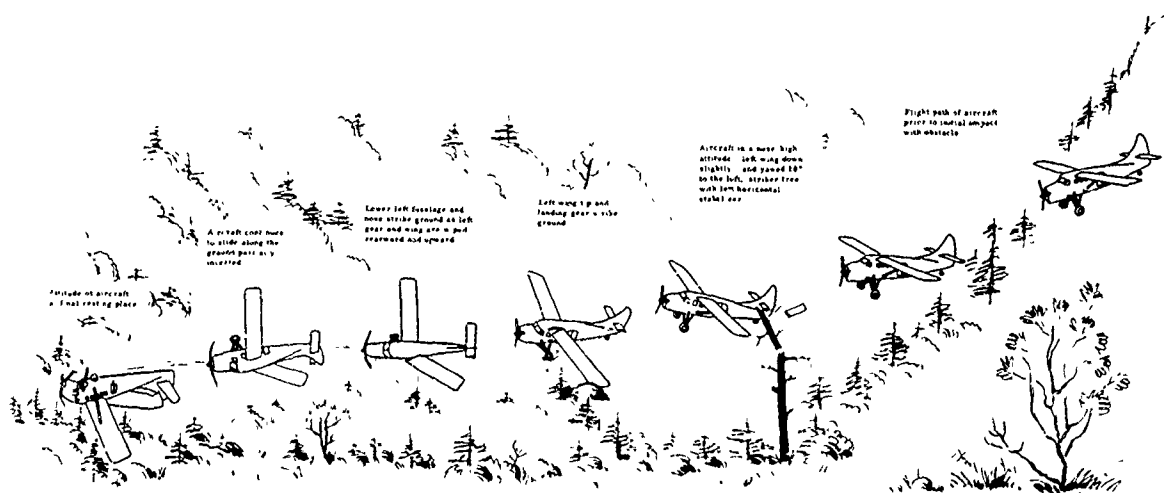
(Reference: TRECOM CRD 2859; AvCIR-10-PR-110)

SECTION II

U. S. ARMY U-1A DeHAVILLAND OTTER ACCIDENT FT. CARSON, COLORADO 16 JUNE 1959*

A U. S. Army DeHavilland Otter crashed with a pilot, a combat scout leader, and 8 combat-equipped troops aboard approximately 5 miles SSW of Ft. Carson, Colorado, at 0925 hours on 16 June 1959.

Following take-off, at an altitude at approximately 25 feet, the aircraft began to settle back toward the ground. The pilot, attempting to maintain flying speed, initiated a descent into an adjacent canyon to avoid striking rough terrain directly off the end of the runway.

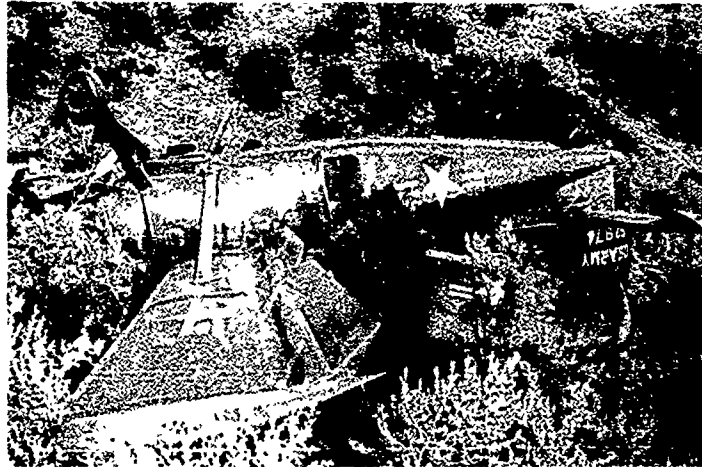


* This accident was investigated under an ONR contract; however, the final report was completed and distributed under the TRECOM contract.



SECTION II

During this descent, the left horizontal stabilizer struck the trunk of a dead tree. The aircraft then struck the side slope of the canyon in extremely rugged terrain impacting on its left wing, nose, and left side



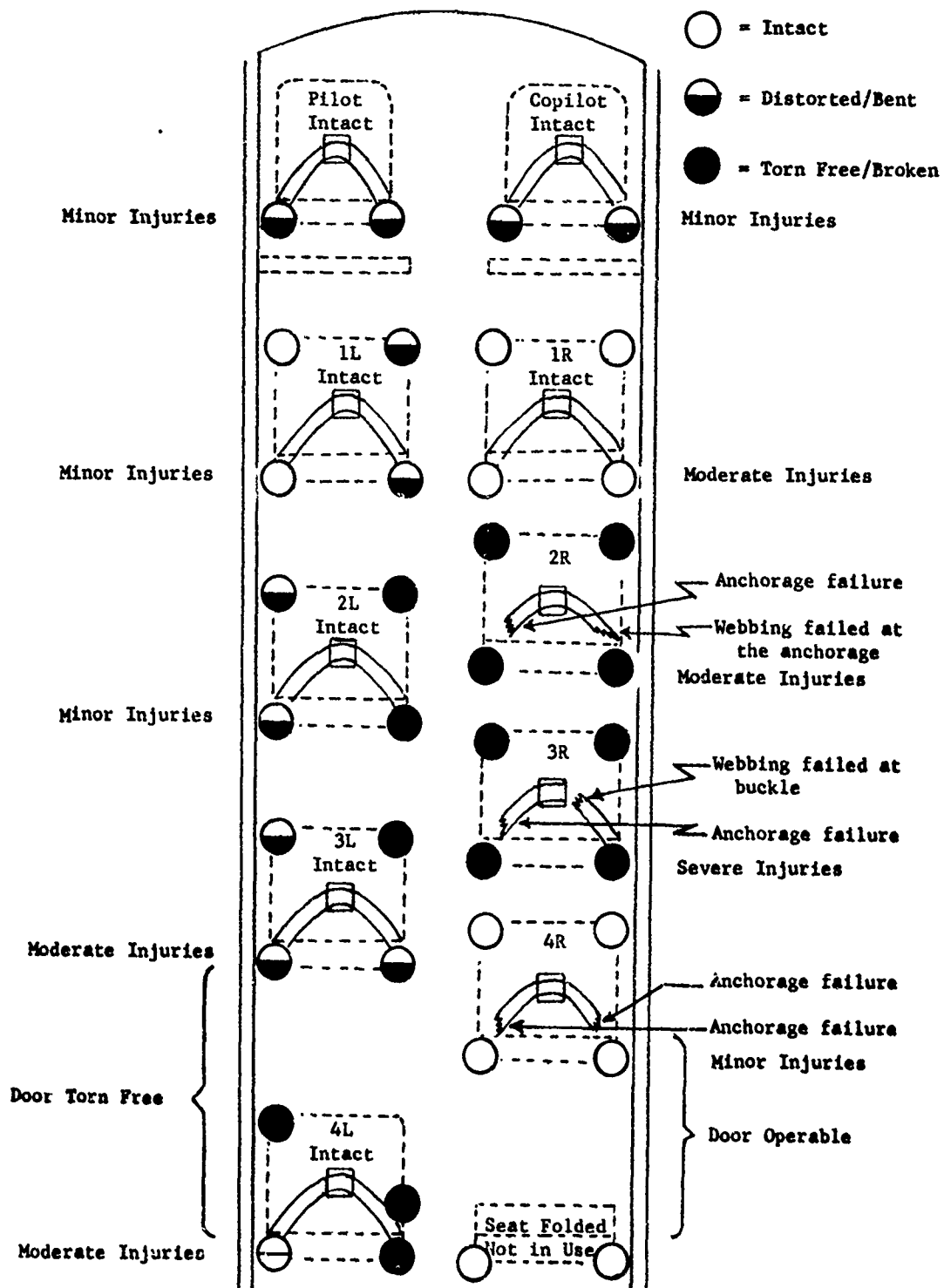
rolling to a partially inverted position before coming to rest approximately 60 feet beyond the point of initial ground impact.

The cockpit and cabin remained reasonably intact. Major damage was sustained by the left wing, the left landing gear, the left lower side of the fuselage, and the engine and nose section. All occupied cabin seats except two were either torn free, broken, or distorted.

The pilot and combat scout leader (who was seated in the copilot's seat) escaped through the broken front windshield. Seven cabin passengers evacuated the aircraft through the left main door which had been torn free. The remaining passengers required assistance from the wreckage. Several of the passengers in the cabin were drenched by gasoline pouring down from the ruptured fuel tanks.

Medical examination revealed that the passengers who required assistance from the aircraft had sustained a dislocated hip and lacerations. Four

SECTION II



SEAT AND SEAT BELT DAMAGE
OCCUPANT INJURIES



SECTION II

passengers had suffered lacerations and abrasions, and the other five occupants had sustained only minor lacerations and abrasions.



The pilot and scout leader (in the copilot's seat) were wearing safety belts and shoulder harnesses. Troops in the cabin were provided with seat belts, some of which failed in the crash.

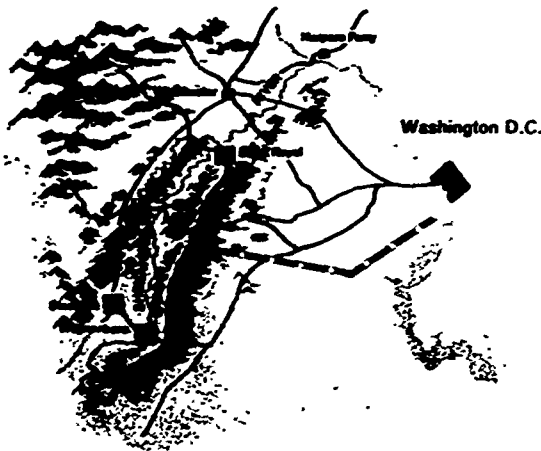
The crash injury investigation conducted on 18-20 June 1959 revealed that the injuries experienced were the result of the occupants' being thrown free due to the seat and/or seat belt failures or striking interior structure and rifles. The analysis of the injury causation factors resulted in recommendations for: (1) increased strength of seats and tie-downs; (2) a more suitable restraint system for occupants; and (3) a method of storing hand-carried weapons.

(Reference: TRECOM CRD 2459; AvCIR-9-PR-104)

SECTION II

U. S. ARMY H-21C SHAWNEE HELICOPTER ACCIDENT BIG MEADOWS, VIRGINIA 2 DECEMBER 1959

The H-21C aircraft involved in this accident was leading a flight of three (3) aircraft ferrying combat-equipped troops from Shannon Airport in Fredericksburg, Virginia, to Big Meadows, Virginia. The intended landing site was situated at the top of a ridge (elevation: 3,800 feet m. s. l.) approximately 6 miles from Luray, Virginia, near the Sky Line Drive.



The approach to the intended landing site was a steep, wooded ravine terminating at a ridge line. Approximately 4 miles from the intended landing site, at approximately 3,400 feet m. s. l., the aircraft experienced difficulty in maintaining air speed and altitude. The pilot continued to add power and pitch to maintain a climb up the ravine until the throttle reached the stops. In spite of application of maximum power, air speed and altitude continued to decrease.

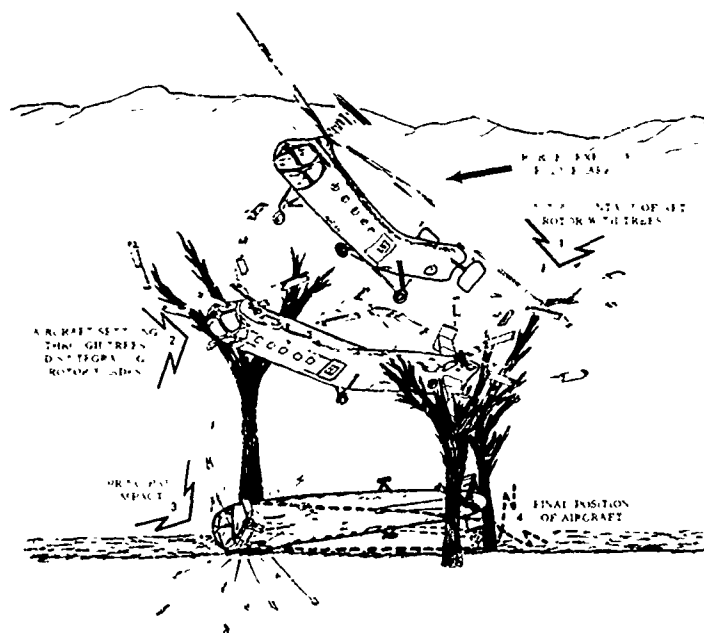
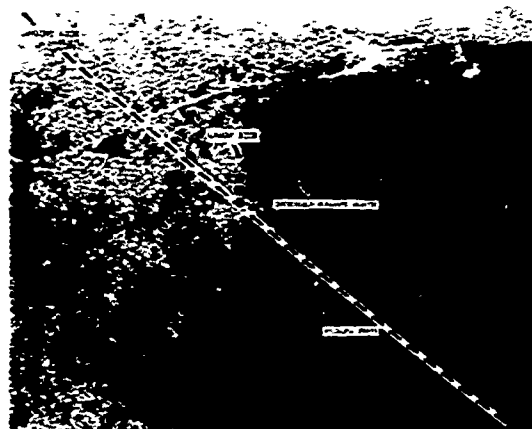
With the other two aircraft in echelon on his left, the pilot attempted to execute a right turn back down the ravine in an attempt to recover from the loss of speed and altitude condition.



SECTION II

As he initiated the turn, however, he found there was insufficient room in the ravine to complete the maneuver and committed the aircraft to a forced landing. He leveled the helicopter and executed a full flare (nose high) to dissipate the remaining air speed and applied

collective pitch to decrease the rate of descent. During this maneuver, the rear rotor contacted the trees and disintegrated, as the aircraft settled into the trees.



During the crash sequence, the aircraft rolled approximately 90 degrees to the left scraping down the sides of the trees approximately 40 feet in height. The aircraft impacted on its left side. Initial ground contact occurred

on the left side of the pilot's compartment forward of the copilot's seat with the aircraft in a 3-5 degree nose-down attitude in relation to the ground. After

SECTION II

initial impact, the rear section of the aircraft settled with the tail cone wedged between several trees.

When the aircraft came to rest, the pilot released himself from his seat which had broken free and evacuated the cockpit through the broken lower portion of the cockpit bubble on the copilot's side. From that position, he released the unconscious copilot from his seat which had also broken free, and removed him from the aircraft. The 12 occupants evacuated the aircraft through the right front cabin door. Some of the more seriously injured troops required assistance in evacuating the aircraft.



Posed photo - Copilot

The copilot received a fatal head injury and died approximately 20 hours after the accident. The pilot and 10 of the passengers received injuries ranging from minor to serious; 3 passengers were uninjured.

The investigation conducted on 5-7 December 1959

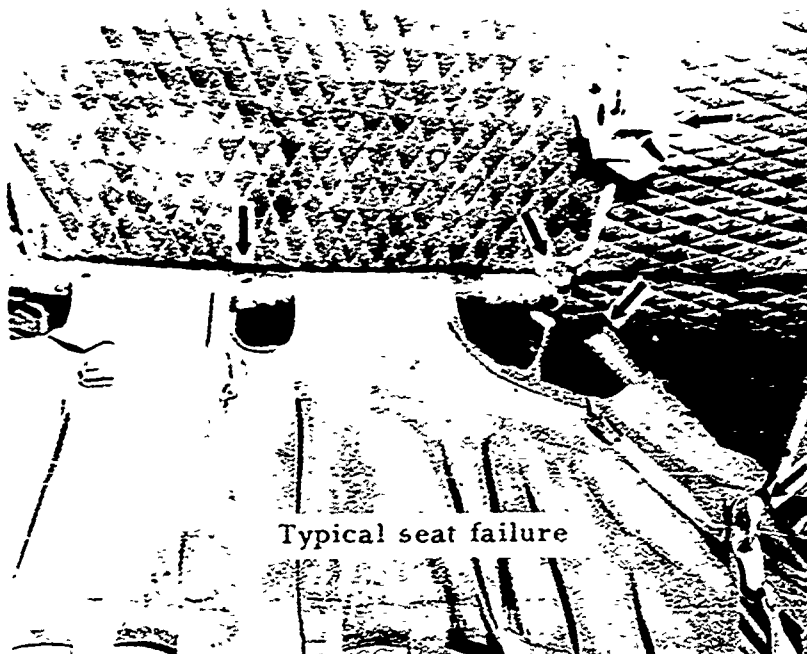
revealed that the predominant causes of injuries were failures of seats and seat belts. The investigation found also that relatively minor damage to the basic aircraft structure resulted from the crash and that the occupiable area of the aircraft,



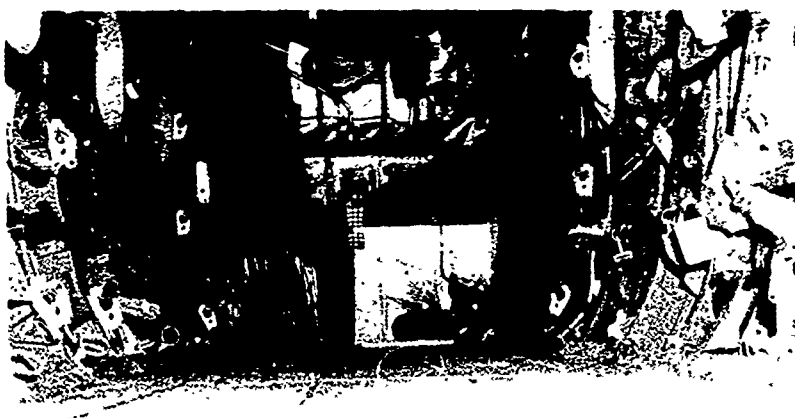
SECTION II

with the exception of the seats and restraining devices, was almost completely intact.

As a result of the findings, it was recommended: (1) that immediate steps be taken toward increasing the integrity of both cockpit and cabin seats and



(2) that consideration be given to attachment of all restraining devices to the basic structure of the aircraft.



Intact condition - floor and fuselage

(Reference: TREC
Technical Report 60-14;
AvCIR-11-PR-112)

SECTION II

U. S. ARMY HU-1A BELL IROQUOIS HELICOPTER ACCIDENT FORT CARSON, COLORADO 9 JUNE 1960

A U. S. Army HU-1A helicopter engaged in the transportation of personnel from Butts AAF, Fort Carson, Colorado, crashed during an attempted landing at 1105 hours on 9 June 1960. The intended landing site was the combat

field range at Fort Carson Military

Reservation (elevation: 6,560 feet m. s. l.)

approximately 9 miles southwest of Butts

AAF, Fort Carson, Colorado.



An approach was made to an intended landing site at the reservation. Observing landing instructions, the pilot initiated a

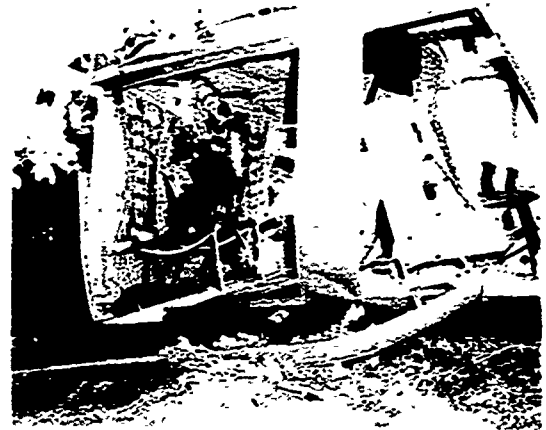
climbing turn to the right. At approximately 270 degrees of the turn and 300 feet of altitude, a partial power failure occurred. The pilot immediately actuated the increase power switch; power increased momentarily and then decreased between partial and full loss of power. The pilot lowered the nose of the aircraft, entered autorotation, and committed the aircraft to a forced landing.

Upon entry into autorotation, the pilot noted a very steep angular approach and an unusually high rate of descent. Just prior to the crash, he succeeded in reducing this high "sink" rate by one-half to approximately 1,500 feet per minute and then executed a full flare.



SECTION II

During the full flare the main rotor blades contacted a large pine tree causing sudden stoppage of the rotor system as the aircraft forcibly contacted the ground. As a result of the sudden stoppage of the rotors, transmission mounts failed, allowing the transmission and its components to penetrate the aft bulkhead into the occupiable area. The decelerative forces in this accident were computed to be



approximately 13 G.



After the aircraft came to rest, the left cabin occupant released himself and evacuated through the left cabin door; the right cabin occupant released himself from a broken seat and evacuated through the right cabin door. Both pilot and copilot released themselves and evacuated through their respective doors. The pilot and copilot sustained spinal strains, and the other two occupants received strains, abrasions, and cuts.

As a result of the investigation conducted on 11-12 June 1960, it was concluded that:

SECTION II

1. The side and rear roof structure provides inadequate support even under conditions of survivable crash forces;
2. Troop seat design (MIL-S-5804B) offers the occupant inadequate protection;
3. Safety belts would offer more protection if attached to available cables rather than to "O" rings; and
4. Inadequate tie-down strength of the transmission (support casting) constitutes a serious hazard to troop seat occupants.

Based upon these conclusions, it was recommended that:

1. The side vertical supports be redesigned to provide for strength requirements compatible with survivable crash force magnitude, directions, and time durations;
2. The specification for the present troop seats be rewritten to provide for increased occupant protection;
3. Troop seat belts be attached to the cables provided for that purpose; and
4. The engine and transmission installations be redesigned to provide strength requirements compatible with survivable crash force magnitudes, directions, and time duration.

(Reference: TREC Technical Report 60-72; AvCIR-12-PR-122; also Crash Injury Bulletin TREC Technical Report 60-61; AvCIR-69-O-120)



SECTION II

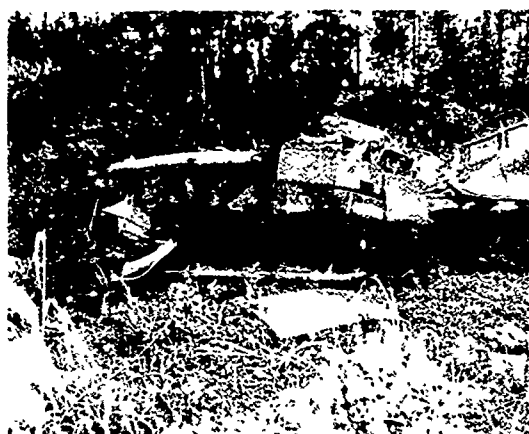
U. S. ARMY HU-1A BELL IROQUOIS HELICOPTER ACCIDENT FORT BRAGG, NORTH CAROLINA 20 AUGUST 1960

A U. S. Army HU-1A crashed at 1455 hours on 20 August 1960 while participating in field exercise "Bright Star" on the Fort Bragg Military Reservation.

The pilot, having entered the downwind leg for the intended landing site, stated that he felt the aircraft settle and immediately noticed a drop in rotor r. p. m. While at approximately 200 feet, he immediately lowered the nose to maintain rotor r. p. m. and committed the aircraft to a forced landing. The immediate area consisted of 50- to 60-foot high pine trees.

As the aircraft entered the wooded area a nose high, full flare was initiated prior to the main rotor severing a 10-inch diameter tree approximately 35 feet above the ground.

From this point the aircraft settled in a tail low attitude until striking the ground. During this latter sequence, the cabin area just aft of the pilot's seat on the right side was impaled on a stump approximately 10 inches high which penetrated into the inhabitable area.



SECTION II

Accurate measurements were unobtainable due to a continuous rain which eliminated most of the gouge marks although evidence indicates the vertical load sustained was approximately 14G while the longitudinal force was approximately 4G.

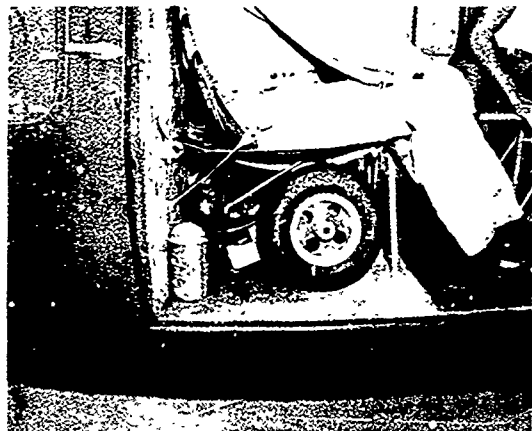
At the time of the crash, there were two crew members and four passengers aboard the aircraft. The injuries received by the occupants ranged from minor to critical.

The investigation conducted on 22-24 August 1960 revealed that the predominant causes of injuries were failures of the seat anchorages and partial collapse of the aft bulkhead supports. A contributing factor was loose gear stowed under the troop seats.

The investigation also found that the occupiable area of the aircraft received extensive damage due to the partial collapse of the aft bulkhead supports, cabin roof, and complete collapse of the side supports.

As a result of the above findings, it was recommended that:

1. Immediate steps be taken toward increasing the integrity of both cabin structure and seats;





SECTION II

2. Adequate restraining devices be employed for all loose equipment that must be carried or to eliminate the carrying of potential injury producing items in the aircraft.

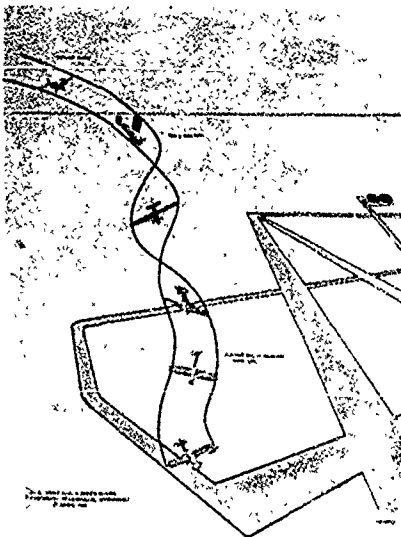
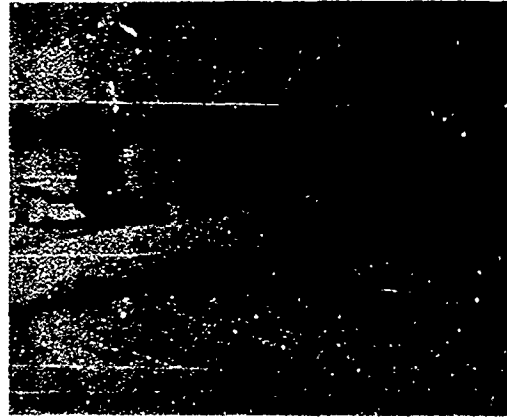
(Reference: TREC Technical Report 60-71, AvCIR-13-PR-123 ; also TREC Technical Report 60-61, AvCIR 69-O-120)

SECTION II

U. S. ARMY L-21A PIPER SUPER CUB ACCIDENT STARKVILLE, MISSISSIPPI 27 APRIL 1960

On 27 April 1960, at approximately 1015 hours, a B. L. C. Modified U. S. Army Piper L-21A crashed on the edge of the Starkville, Mississippi airport while on a demonstration flight.

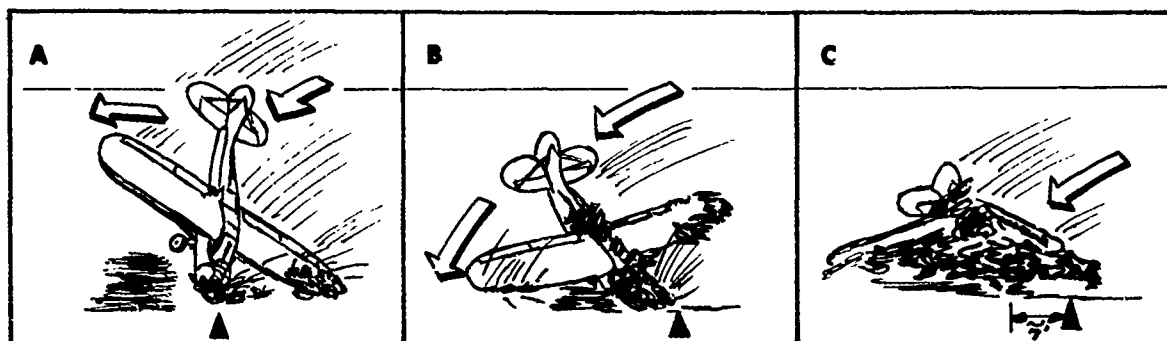
During the demonstration, the aircraft was observed making short take-offs and slow landings, making steeply banked turns at slow speeds and low altitudes (between 100 and 200 feet) and, at another time during this flight, cruising between 1,000 and 2,000 feet altitude.



The aircraft was examined at the crash site on 29-30 April 1960. Photographs of the wreckage and of essential components and equipment were made during the course of the investigation. There were no witnesses to the accident; however, gouges in the ground and aircraft damage details, together with a graphic plotting of wreckage distribution, made it possible to reconstruct the kinematics of the crash sequence - basically a low altitude stall-spin. Estimation of the flight path angle, velocity, impact conditions, stopping

distances, etc., were utilized to calculate the principal crash force.

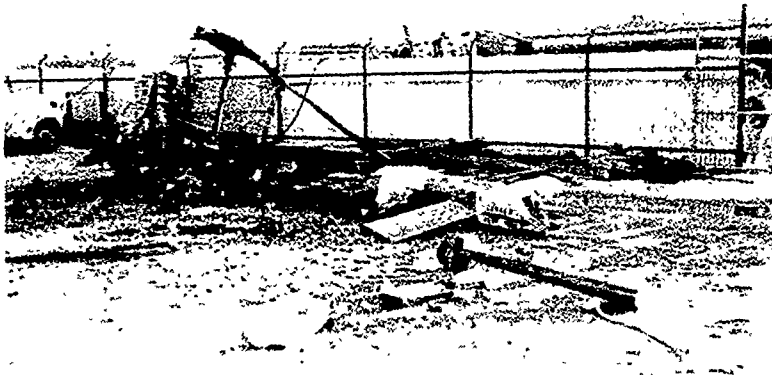
In view of both crash force magnitude and direction, as well as the extent of aircraft damage, this accident was considered non-survivable.



Consequently, no recommendations relating to crash survival were made and the report was presented in draft form only.

SECTION II

U. S. ARMY YH-41
CESSNA HELICOPTER ACCIDENT
PHOENIX, ARIZONA
8 MAY 1960



A U. S. Army
YH-41 Cessna heli-
copter crashed during
a flight from Sky Harbor
Airport, Phoenix,
Arizona, 8 May 1960.

The pilot experi-
enced failure of the tail
rudder just after take-off, the aircraft went out of control, crashed, and burned.

The pilot was thrown free of the aircraft at impact; a passenger trapped
inside was rescued by a witness.

The accident was investigated on 8-9 May 1960. There is some indication
that the rerouting of the exhaust manifold from the proximity of the fuel tank in
this aircraft might prevent similar post-crash fire.

A report has been prepared in memorandum form only.



SECTION II

U. S. ARMY H-13G
BELL HELICOPTER ACCIDENT
FORT DEVENS ARMY AIRFIELD
FORT DEVENS, MASSACHUSETTS
1 JULY 1960

A U. S. Army H-13G Bell helicopter, engaged in a training flight, crashed at 0854 hours, 1 July 1960 at Fort Devens, Massachusetts.

The instructor pilot, demonstrating an aborted take-off to the student pilot, took off and climbed to approximately 100 feet, stopped the aircraft, and began rearward flight. The tail pitched up, and the aircraft dove into the ground at a 65-degree



angle impacted on the right (instructor pilot) side. The aircraft was demolished.

The instructor pilot received fatal internal injuries; the pilot experienced lacerations of the chin and chest.

Investigation revealed that shoulder harnesses are not available in the G model of the H-13. This contributed to the injuries received by the occupants.

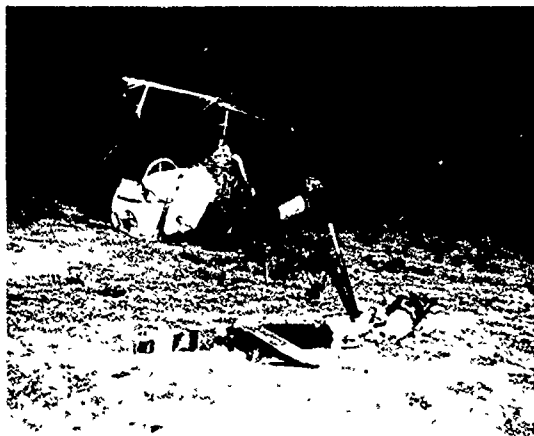
The detailed findings of this accident are presented in memorandum form only.



SECTION II

U. S. ARMY NATIONAL GUARD H-23C HILLER HELICOPTER ACCIDENT PHOENIX, ARIZONA 8 DECEMBER 1960

A U. S. Army National Guard H-23C Hiller helicopter was inadvertently flown into the ground while the pilot was in the process of selecting a suitable area to practice night landings; it crashed at approximately 2010 hours, 8 December 1960, in northeast Phoenix, Arizona.



With position and landing lights on, the aircraft struck the ground slightly nose-down in a gentle left turn at 50 to 60 knots forward velocity. The left skid hit first, followed by the left front underside of the cockpit. The rotors appeared to have flexed down into the tail boom, shattering the blades and tearing the tail boom into two main sections.

Investigation conducted on 8-9 December 1960 indicated that the latch on the safety belt did not hold throughout the crash sequence, for reasons still undetermined. During the initial impact, the belt held just long enough to allow the pilot to flex forward, at which point the buckle opened, allowing the pilot to go head down, backwards, through the upper portion of the bubble out of the aircraft.

The pilot sustained minor injuries.

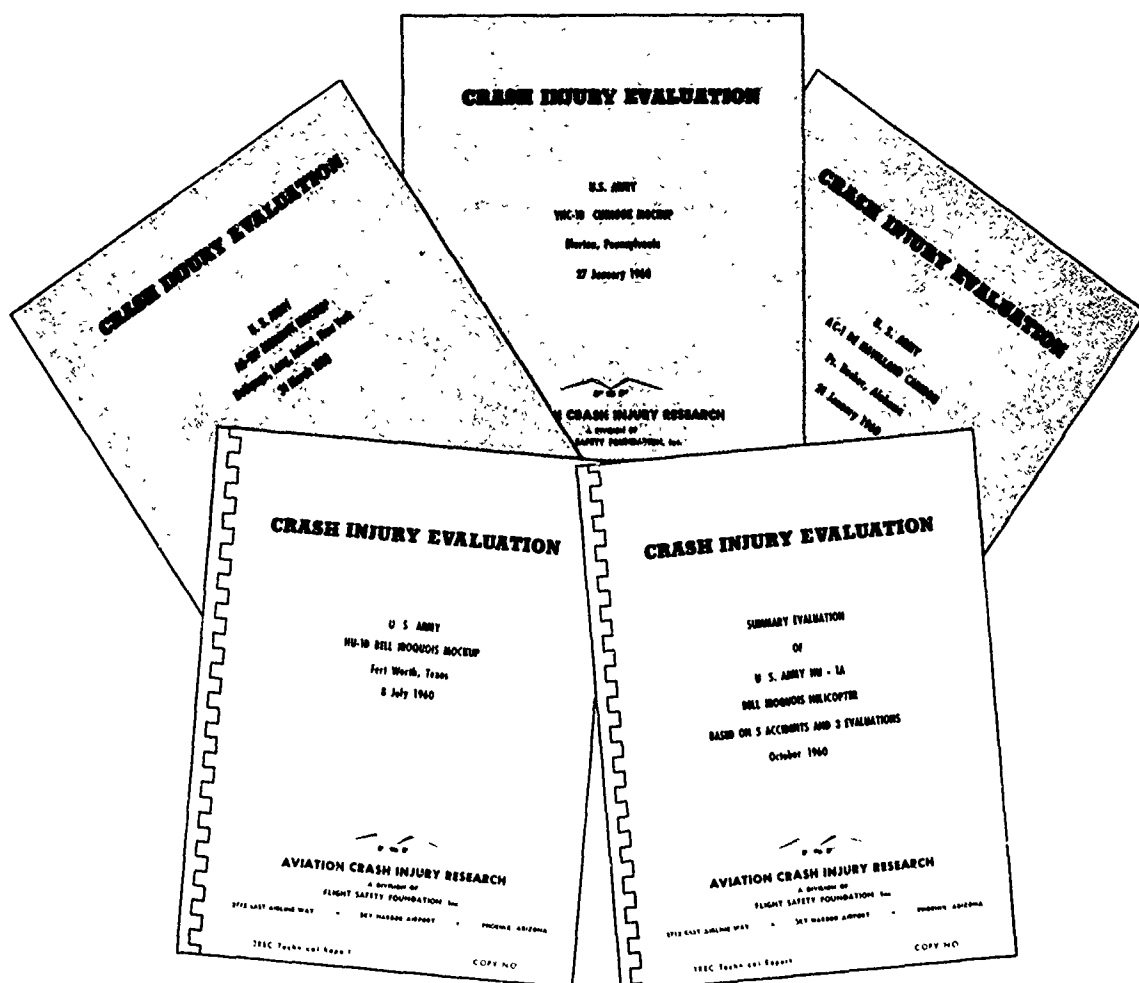
The detailed findings of this accident are being analyzed and preparation of the draft report is under way.



SECTION III

CRASH INJURY EVALUATION

Using knowledge gained from numerous accident investigations, it is possible to judge crash injury and crashworthiness characteristics of existing aircraft, of proposed manufacturer's designs, and of mock-ups. This enables consideration of desirable design changes and possible correction prior to the time when the aircraft may become involved in a survivable accident.



SECTION III

During the reporting period, crash injury evaluations were conducted on two (2) operational Army aircraft, four (4) Army aircraft mock-ups, and comments were submitted for incorporation in the military and technical characteristics of a new Army aircraft type. One of the operational aircraft evaluations consisted of the consolidated findings of five (5) accidents involving this aircraft plus three (3) separate evaluations of the same aircraft beginning with the original mock-up of the X-model in 1955.

AO-1BF Mohawk Mock-up
Bethpage, Long Island, New York

TREC Technical Report 60-45
AvCIR-12-PV-117
August 1960

YHC-1B Chinook Mock-up
Morton, Pennsylvania

TREC Technical Report 60-54
AvCIR-13-PV-118
September 1960

AC-1DH DeHavilland Caribou
Ft. Rucker, Alabama

TREC Technical Report 60-62
AvCIR-14-PV-121
October 1960

Summary Evaluation
U. S. Army HU-1A
Bell Iroquois Helicopter
(Based on Five Accidents and Three
Evaluations)

TREC Technical Report 60-73
AvCIR-15-PV-126
December 1960

U. S. Army: HU-1B Mock-up
Bell Iroquois Helicopter
Ft. Worth, Texas

Memorandum report only

U. S. Army: HU-1D Mock-up
Bell Iroquois Helicopter
Ft. Worth, Texas

TREC Technical Report 60-74
AvCIR-16-PV-127
December 1960



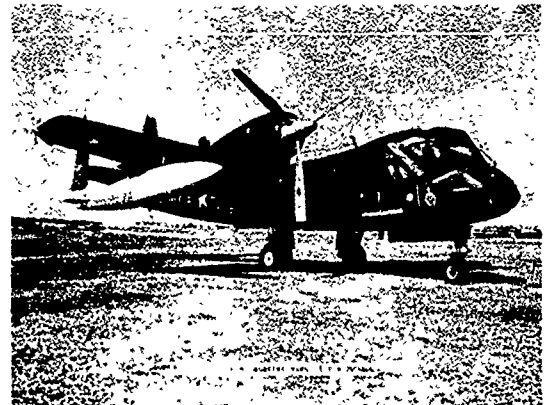
SECTION III

U. S. ARMY
AO-1BF MOHAWK MOCK-UP
BETHPAGE, LONG ISLAND, NEW YORK
31 MARCH 1960

On 31 March 1960, a crash injury evaluation of the Grumman AO-1BF U. S. Army Mohawk was conducted at the time of a regular Mock-up Board evaluation.

The evaluation revealed that the Mohawk incorporates many desirable features which generally help prevent injuries in the event of an accident:

1. The cockpit is stressed for 40G;
2. The Martin-Baker ejection seats currently being utilized incorporate two desirable features, a 40G seat and a continually locked shoulder harness;
3. The self-sealing fuel tank is located in the fuselage above the center section with two bulkheads separating the fuel tank area from the cockpit;
4. Protection is afforded by the 1-inch thick windshield and the utilization of 1/2-inch armor plate for the cockpit floor; and
5. The relatively slow landing speed is another of the desirable features incorporated into the Mohawk.

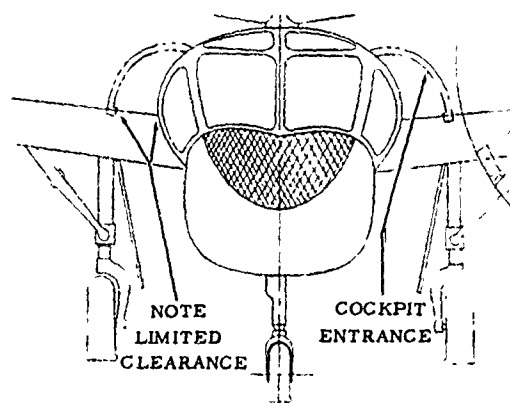


SECTION III

The evaluation also revealed certain undesirable features that may contribute to injuries in the event of an accident:

1. The pilot's instrument panel, the eyebrow panels, and the overhead console contain a large assortment of knobs, switches, and protruding instruments which could produce head injuries. A large number of sharp edges and corners also are present around the instruments. The possibility of getting all of the instruments, knobs, and switches recessed or the instrument panel adequately padded is quite remote. Therefore, in order for the occupants to obtain maximum protection at all times, it must be stressed emphatically that the restraint system, safety belt, and shoulder harness, plus the helmet, be utilized at all times in the prescribed manner.
2. The operation of the side entrances, the limited clearance when the side panels are in an open position, and the inability to jettison these

side panels under emergency conditions could delay the evacuation of injured occupants.





SECTION III

As a result of the above findings, it was recommended that:

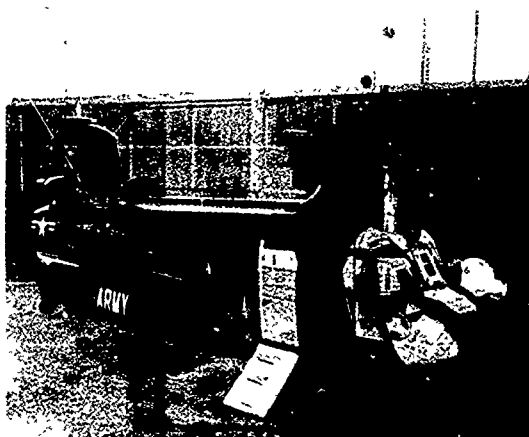
1. Orders be issued making it mandatory that crew members utilize the restraint system and hard hats at all times while flying the Mohawk; and
2. Consideration be given to making the side panels jettisonable from both the interior and the exterior.

(Reference: TREC Technical Report 60-45; AvCIR-12-PV-117)

SECTION III

U. S. ARMY
YHC-1B CHINOOK MOCK-UP
MORTON, PENNSYLVANIA
27 JANUARY 1960

The U. S. Army model YHC-1B helicopter mock-up was presented for a board review by the Vertol Aircraft Corporation, Morton, Pennsylvania,



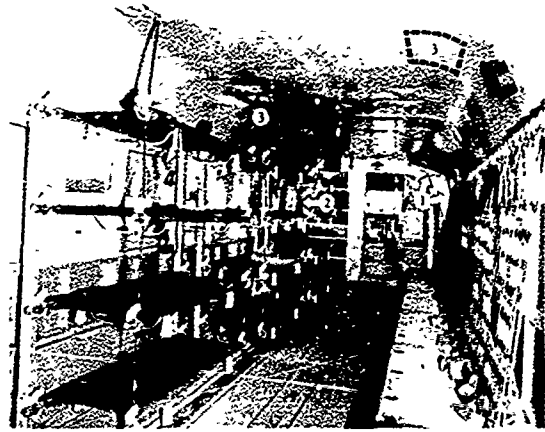
27 January 1960, at which time an evaluation of the aircraft from a crash survival point of view was made. As a result of the evaluation, based in part on previous accident experience, it was concluded that a number of desirable crash safety features exist:

1. The crew compartment and main cabin generally appear to offer crashworthy features free from the great number of protruding, injurious components usually found in earlier model Army troop-carrying helicopters;
2. The YHC-1B presents a good cockpit arrangement with the instrument panel mounted low and out of striking range for an adequately restrained pilot and copilot;
3. Objects such as overhead consoles, lights, and motors are installed and mounted in a recessed manner thereby removing them from striking range of the pilot and copilot; and
4. Provisions for emergency exits in the crew compartment are adequate.



SECTION III

The evaluation also revealed a number of crash safety deficiencies existing in troop seats, litter installations, and emergency escape facilities. Certain injurious environmental factors in the main cabin were revealed. In addition, certain military specifications governing the design and strength of various components such as seats, litters, etc. appear to be deficient in that minimum requirements specified are inadequate and incompatible with today's concept of magnitudes, directions, and time exposures of crash forces within survivable limits.



Based on the data and analyses presented in this evaluation, several recommendations were made concerning the flight control area, the main cabin, the airframe itself, and certain specifications. Full details are found in the referenced report.

(Reference: TREC Technical Report 60-54; AvCIR-13-PV-118)

SECTION III

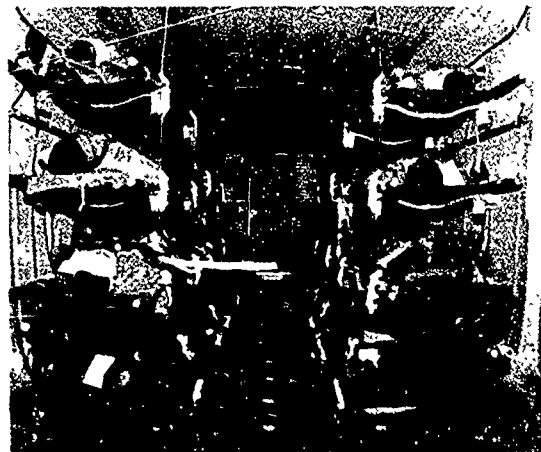
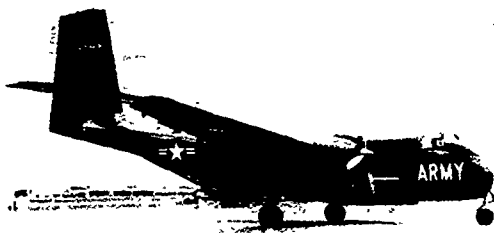
U. S. ARMY
AC-1 DEHAVILLAND CARIBOU
FT. RUCKER, ALABAMA
21 JANUARY 1960

A crash injury evaluation of the U. S. Army AC-1 DH Caribou conducted

at Ft. Rucker, Alabama on 21 January 1960 disclosed several desirable crash safety features including : (1) a limit landing gear strength which permits a vertical rate of descent of 14 feet per second; (2) the location of the fuel cells outboard of the engine nacelles; and

(3) the manner in which the troop seat belts are anchored.

The evaluation also revealed a number of undesirable crash safety features such as: (1) the insufficient load requirements in the troop seat specification (MIL-S-5804B); (2) inadequate and incomplete load requirements for litter installations (MIL-S-5705); (3) insufficient number and poor location of emergency exits in the cabin; and



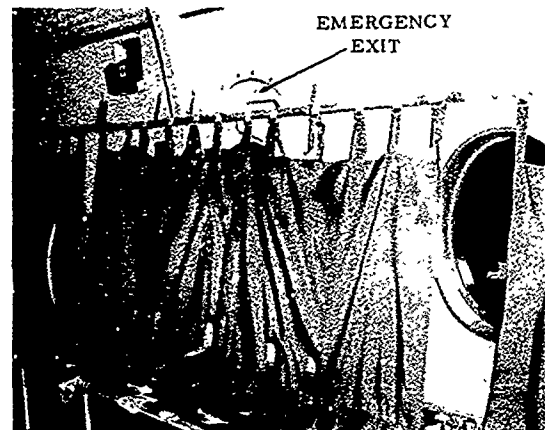


SECTION III

(4) inadequate instructions for operation of emergency exits.

As a result of these and other findings, it was recommended, for example, that:

- (1) The specifications for seat belts, troop seats, and litter installations be subjected to close scrutiny to determine revisions needed for increased occupant protection;
- (2) The number of emergency exits in the cabin section be increased; and
- (3) The instructions for operation of the emergency exits be made more explicit.



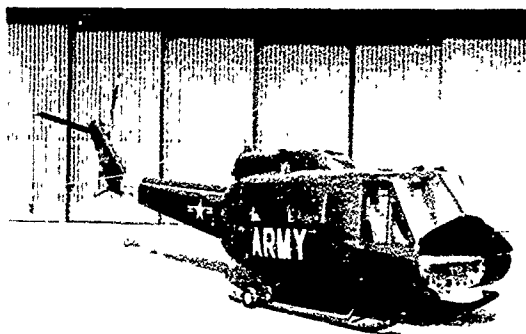
These and other details will be found in the referenced report.

(Reference: TREC Technical Report 60-62; AvCIR-14-PV-121)

SECTION III

U. S. ARMY HU-1D
BELL IROQUOIS HELICOPTER MOCK-UP
FORT WORTH, TEXAS
8 JULY 1960

On 7 July 1960, a crash injury evaluation of the Bell HU-1D U. S. Army Iroquois was conducted in Fort Worth, Texas. Analysis of the information



obtained indicates that some of the desirable crash safety features of earlier models have been incorporated in this model, such as: (1) energy absorption characteristics of the skid gear, (2) resistance of the basic floor structure to deformation, and (3) breakaway char-

acteristics of console, instrument panel, and the tail boom.

The analysis also revealed certain undesirable crash safety features, such as: (1) inadequate transmission support, (2) troop seat design and configuration, and (3) location of fuel cells in the belly.

Based upon these findings, it was recommended that:





SECTION III

1. Increased support be provided for the transmission;
2. The troop seat specification be revised to provide increased occupant protection; and
3. The fuel cell installation be subjected to dynamic testing to determine its adequacy under crash conditions.

(Reference: TREC Technical Report 60-74; AvCIR-16-PV-127)

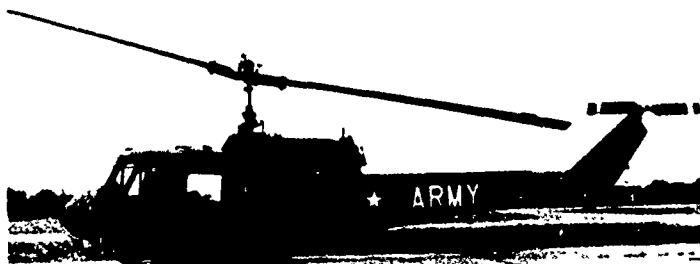
SECTION III

SUMMARY EVALUATION U. S. ARMY HU-1A BELL HELICOPTER BASED ON THREE EVALUATIONS AND FIVE ACCIDENTS OCTOBER 1960

The first crash injury evaluation of what is now the HU-1A was conducted on an XH-40 mock-up by Aviation Crash Injury Research of Cornell University, now a division of the Flight Safety Foundation, on 15 November 1955, Fort Worth, Texas.

The United States Army Board for Aviation Accident Research, in conjunction with the United States Army Aviation Board, United States Army Transportation Aircraft Test and Support Activity, and the Aviation School's Flight Surgeon's Office conducted an evaluation of the test model of the YH-40 on 4 and 5 November 1958 at Fort Rucker, Alabama. This evaluation also covered a second YH-40 that had been wrecked.

A third evaluation was on a production model of the HU-1A conducted by AvCIR on 22 January 1960 at Fort Rucker, Alabama.



In addition to these evaluations, a comparison study of five HU-1A accidents was made. The accidents included were as follows:

HU-1A, 21 October 1959
East St. Louis, Illinois
Investigated by Aviation Crash
Injury Research Personnel



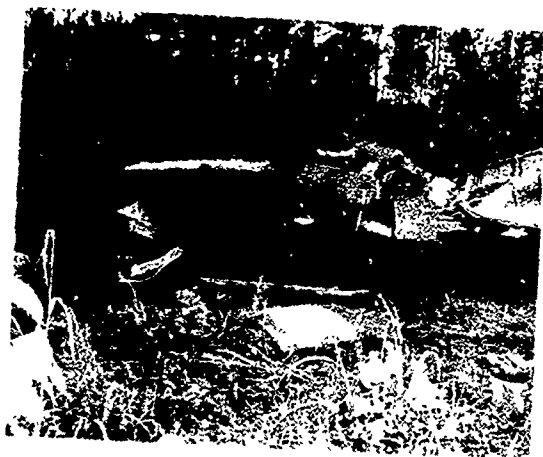
HU-1, 3 March 1960
Fort Rucker, Alabama
Investigated by Army
Personnel



HU-1A
9 June 1960
Fort Carson, Colorado
Investigated by Aviation Crash
Injury Research Personnel



SECTION III



HU-1A
20 August 1960
Fort Bragg, North Carolina
Investigated by Aviation Crash
Injury Research Personnel

HU-1A
26 August 1960
Fort Rucker, Alabama
Investigated by Army
Personnel



The accidents which occurred at East St. Louis, Fort Carson, and Fort Bragg were investigated by AvCIR. The material for the two (2) other accidents was extracted from the United States Army Accident Reports.



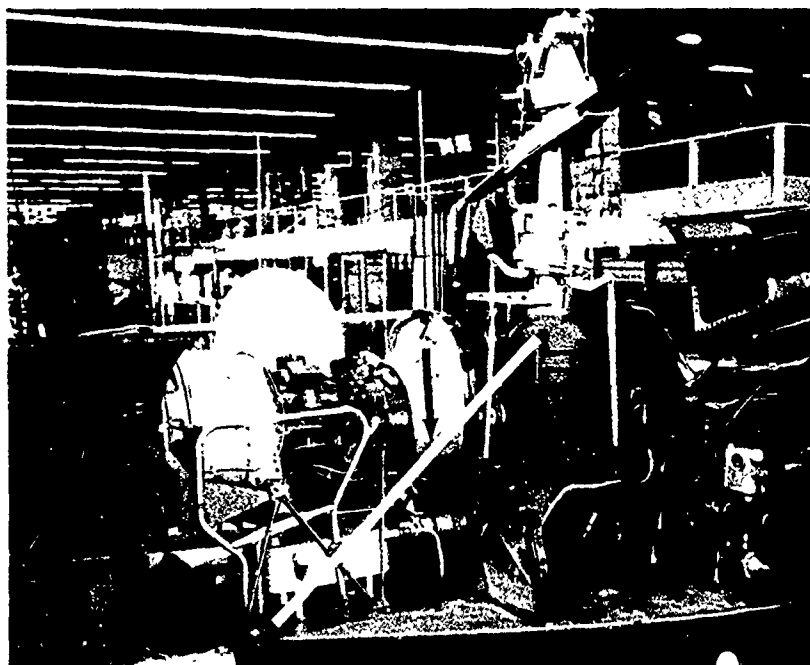
SECTION III

The first evaluation by AvCIR on 15-16 November 1955 cited many specific hazards relating to litter installations, troop seats, crew seats, safety belt installations, and similar items. Perhaps the most significant item cited, however, was the strength of mounting the transmission. For this the following comment was made:

"It appears that crash loads will cause the transmission unit to break free and pass downward through the cabin bulkhead into the cabin, thereby crushing the occupants."

A suggestion of a tension tie (cable or tube), as illustrated below, was made.

During the second evaluation by USABAAR, many of the same points were made with specific mention of the failure of the transmission mount in the wrecked YH-40. There also was transmission



failure in all five (5) accident cases with the transmission going into the cabin area with serious results in one of the accidents.

In summary, both desirable and undesirable features were found as a result of the three (3) evaluations and the investigation of five (5) accidents

SECTION III

in relation to crash safety.

The desirable features are summarized as follows:

- (1) The skid-type landing gear utilized on the HU-1A absorbs a considerable amount of energy during an accident;
- (2) The seat cushions currently being used in the crew members' seats also absorb a considerable amount of energy;
- (3) The location of the fuel tanks, aft of the passenger compartment and on the sides of the aircraft, is an improvement over those which are located in the belly of most helicopters.

Undesirable features which might or actually have contributed to injuries in an accident were found to be:

- (1) The structural integrity of the vertical side supports and of the aft roof supports is insufficient to withstand survivable crash forces;
- (2) The troop seats are structurally inadequate; and
- (3) The tie-down strength of the transmission is insufficient to withstand even moderate survivable crash forces.

In keeping with these findings, it has been recommended that:

- (1) The side vertical supports be redesigned to provide increased strength requirements compatible with survivable crash force magnitude, directions, and time duration;
- (2) The specification for the present cabin seat design be rewritten to provide for increased occupant protection; and



SECTION III

- (3) The engine and transmission installations be redesigned to provide increased strength requirements compatible with survivable crash force magnitude, directions, and time duration.

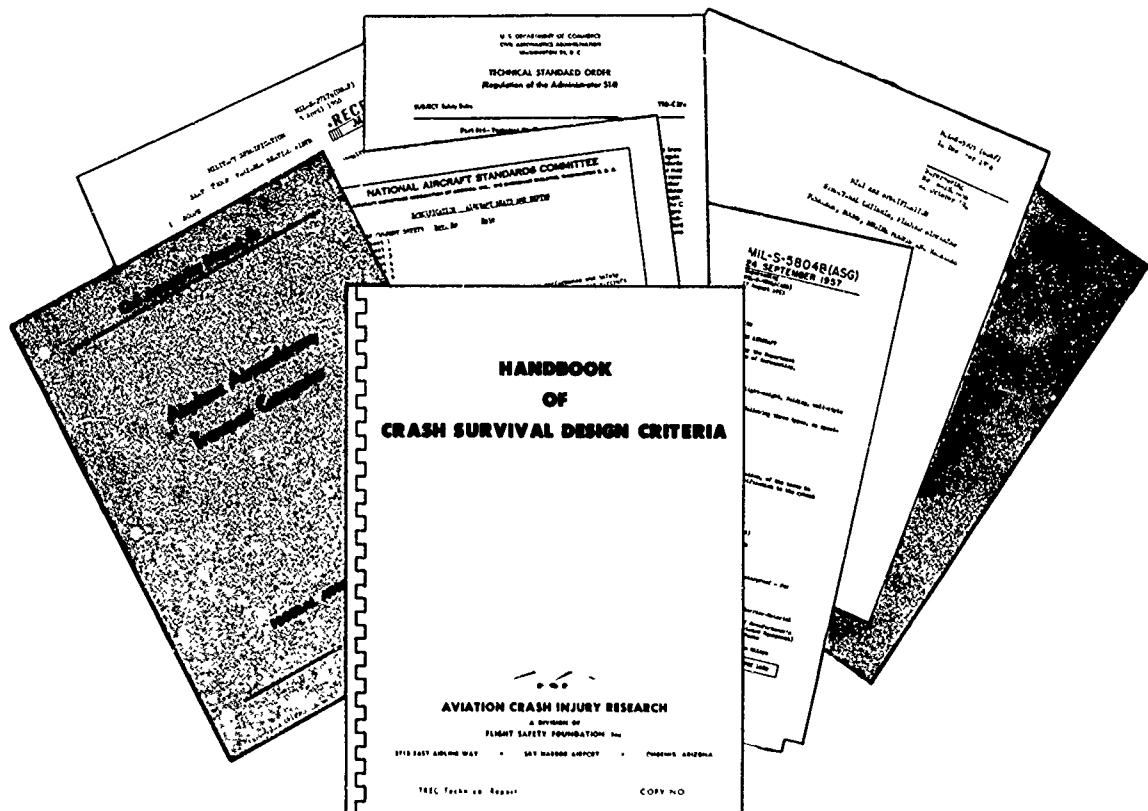
(Reference: TREC Technical Report 60-73; AvCIR-15-PV-126)



CRASH SURVIVAL DESIGN CRITERIA

AvCIR continues to gather and review specifications, technical standard orders, and related material from military and civilian sources, and from foreign sources as well, with the ultimate objective of categorizing them into a "Handbook of Crash Survival Design Criteria."

An initial outline for such a handbook has been agreed upon and is presented in this section.



SECTION IV

HANDBOOK OF CRASH SURVIVAL DESIGN CRITERIA

A. General Concepts

1. Terminology
2. Crash Forces
 - a. prolonged and abrupt accelerations
 - b. kinetic energy vs. stopping distance and decelerative force
 - c. energy absorption
 - d. dynamic response and load amplification
 - e. transmission of crash force
3. The Mechanism of Crash Injuries
 - a. human G tolerance
 - b. kinematic behavior of human body during decelerations
 - c. modus of injury
 - d. injury patterns
 - e. principles of protection
4. Crash Safety Criteria
 - a. impact survival
 - (1) crashworthy basic structure
 - (2) adequate occupant tie-down chain
 - (3) non-injurious occupant environment
 - b. evacuation
 - (1) post-crash fire protection
 - (2) adequate emergency exits

B. Fixed Wing Aircraft

1. Crashworthiness
 - a. structural integrity of occupiable area
 - (1) cockpit
 - (2) cabin
 - b. variation of G-loads with distance from point of impact
 - c. structural collapse and energy absorption
2. Occupant Tie-Down Chain
 - a. present tie-down requirements
 - b. static vs. dynamic strength
 - c. floor structure
 - d. seats (crew - passenger) and anchorages
 - e. seat belts and anchorages
 - f. shoulder harness and inertia reels



3. Occupant Environment
 - a. injury potential
 - (1) cockpit
 - (2) cabin
 - (3) galley
 - b. protective padding vs. adequate tie-down
 - c. crash helmets

4. Evacuation
 - a. post-crash fire hazards
 - b. emergency exit requirements
 - c. other post-crash factors

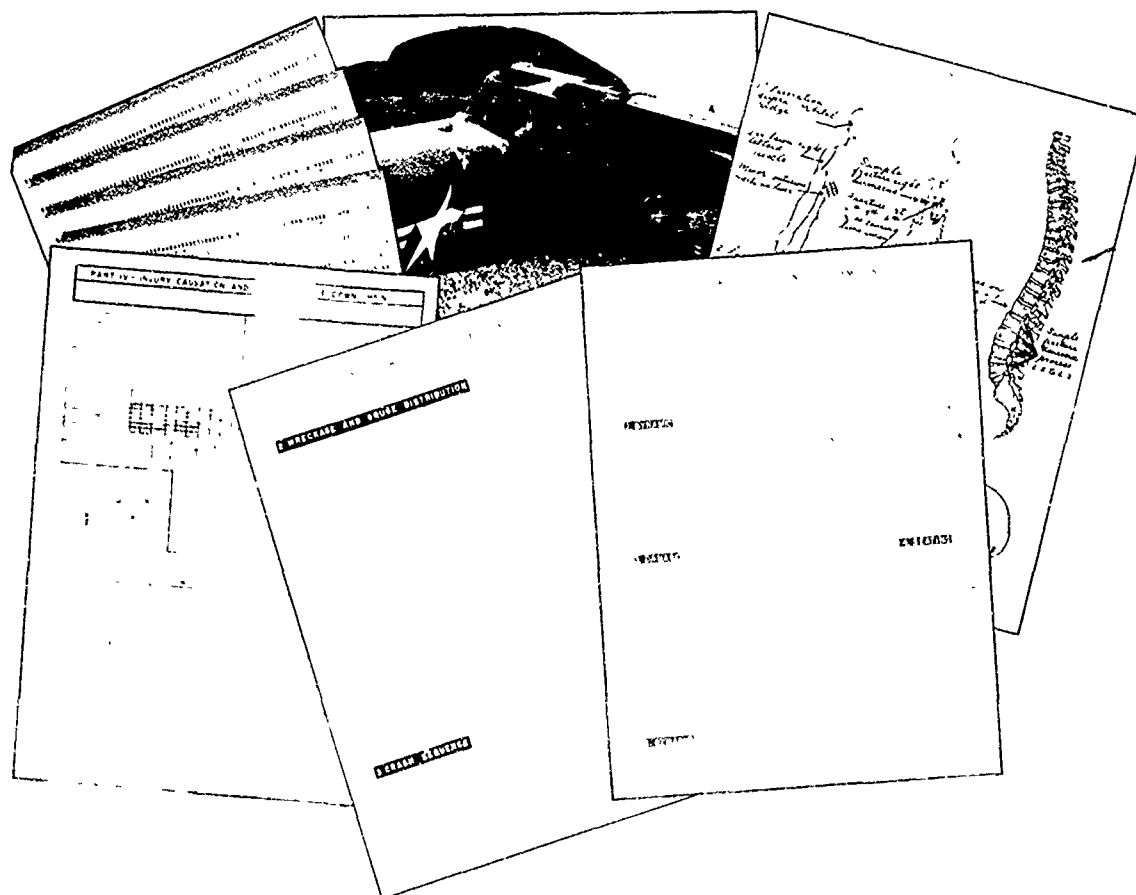
C. Rotary Wing Aircraft

1. Crashworthiness
 - a. structural integrity of occupiable area
 - (1) cockpit
 - (2) cabin
 - b. variation of G-loads with distance from point of impact
 - c. structural collapse and energy absorption
2. Occupant Tie-Down Chain
 - a. present tie-down requirements
 - b. static vs. dynamic strength
 - c. floor structure
 - d. seats (crew - passenger) and anchorages
 - e. seat belts and anchorages
 - f. shoulder harness and inertia reels
3. Occupant Environment
 - a. injury potential
 - (1) cockpit
 - (2) cabin
 - (3) galley
 - b. protective padding vs. adequate tie-down
 - c. crash helmets
4. Evacuation
 - a. post-crash fire hazards
 - b. emergency exit requirements
 - c. other post-crash factors



QUANTITATIVE ANALYSIS OF ACCIDENT DATA

Major support for conclusions and recommendations with respect to crash safety design comes from thorough analysis of mass aircraft accident data, both engineering and medical, obtained from routine reporting of survivable accidents by military and civilian agencies. Detailed reports on special AvCIR accident and medical forms are received routinely from offices of the Federal Aviation Agency, the Civil Aeronautics Board, state aviation agencies, and state police groups.



SECTION V

During the past year, major attention has been given to a review and re-evaluation of the entire data collection, data processing, and data analysis methods and procedures being used. This was supported to a major degree by supplemental funds from the National Institutes of Health of the U. S. Public Health Service, particularly in the field of light-plane accidents.

A number of deficiencies or weaknesses were found to exist and positive steps have been taken to correct them. Of major significance was the development of a new, condensed report form which would greatly simplify the task of reporting by field investigators and yet still provide the critical, pertinent information needed for crash injury analysis. The form currently is undergoing trial application in the field.

Numerous experimental tabulations have been conducted as part of the review and re-evaluation. These have been carried to the point where it has been possible to schedule eight (8) special statistical studies, a number of which already are under way.

(1) Prediction of Degree of Injury from Accident Variables in Lightplane Accidents. This is a study to determine the extent to which degree of injury is predictable from single, gross accident variables. Analyses are being made of data from 913 lightplane accidents occurring from 1942 to 1952. Intercorrelations between the following variables are being obtained: degree of injury, impact velocity, angle of impact, stopping distance, cabin damage, occupant environment damage, and rated accident severity.



(2) Relationship Between Tie-Down Effectiveness and Injuries Sustained in Lightplane Accidents (1942 - 1952). The purpose of this study is to gain a better understanding of the relationship between tie-down effectiveness and type and degree of injury. Analyses are being based on a sample of 1,369 occupants involved in spin-stall and collision accidents during the period 1942 to 1952. Effects of seat belt failure and seat dislodgment on injuries sustained are being evaluated as a function of rated accident severity, angle of impact, impact velocity, and stopping distance.

(3) Relationship Between Impact Variables and Injuries Sustained in Lightplane Accidents (1942 - 1952). The objective of this study is to determine the relationship between type and degree of injury and rated accident severity, impact velocity, angle of impact, and stopping distance. Analyses are being based on a sample of "front-seat" occupants involved in spin-stall and collision accidents during the period 1942 to 1952. Injuries to 18 specific body areas are being evaluated with the objective of providing recommendations for safer design practices.

(4) Relationship Between Tie-Down Effectiveness and Injuries Sustained in Lightplane Accidents (1953 - 1960). This study is the same as No. 2 except for the sample period. Here, analyses are being based on a sample of approximately 1,034 occupants involved in spin-stall and collision accidents during the period 1953 to 1960. Effects of seat belt failure and seat dislodgment on injuries sustained are being evaluated as a function of rated accident severity, angle of impact, impact velocity, and stopping distance.

SECTION V

(5) Relationship Between Impact Variables and Injuries Sustained in Lightplane Accidents (1953 - 1960). This study is the same as No. 4 except for the period of the sample. Here, analyses are being based on a sample of "front-seat" occupants involved in spin-stall and collision accidents during the period 1953 to 1960. Injuries to 18 specific body areas are being evaluated with the objective of providing recommendations for safer design practices.

(6) Factor Analysis of Aircraft Crash Variables. This study is an application of the technique of factor analysis to measures of damage and impact conditions in order to determine those factors which are basic to an understanding of the crash picture. A sample of approximately 200 cases representing a reasonably homogeneous crash picture have been selected from data on 500 lightplane crashes which occurred between 1953 and 1960. Seven pre-crash, six post-crash, and twenty-one damage measurements enter into the analysis.

(7) Development of an Aircraft Damage Rating Scale. Inexperienced subjects will rate degree of structural damage from slides. Results obtained from the use of different lengthed scales will be analyzed to determine the number of scale steps providing the most reliable discrimination. A second study will be concerned with determination of meaningful verbal labels to anchor the rating scale steps.

(8) Reliability of Investigator Ratings. Both inexperienced and experienced investigators will rate damaged aircraft structures which will be judged against varying degrees of background damage. Reliability of the rating scale will be



SECTION V

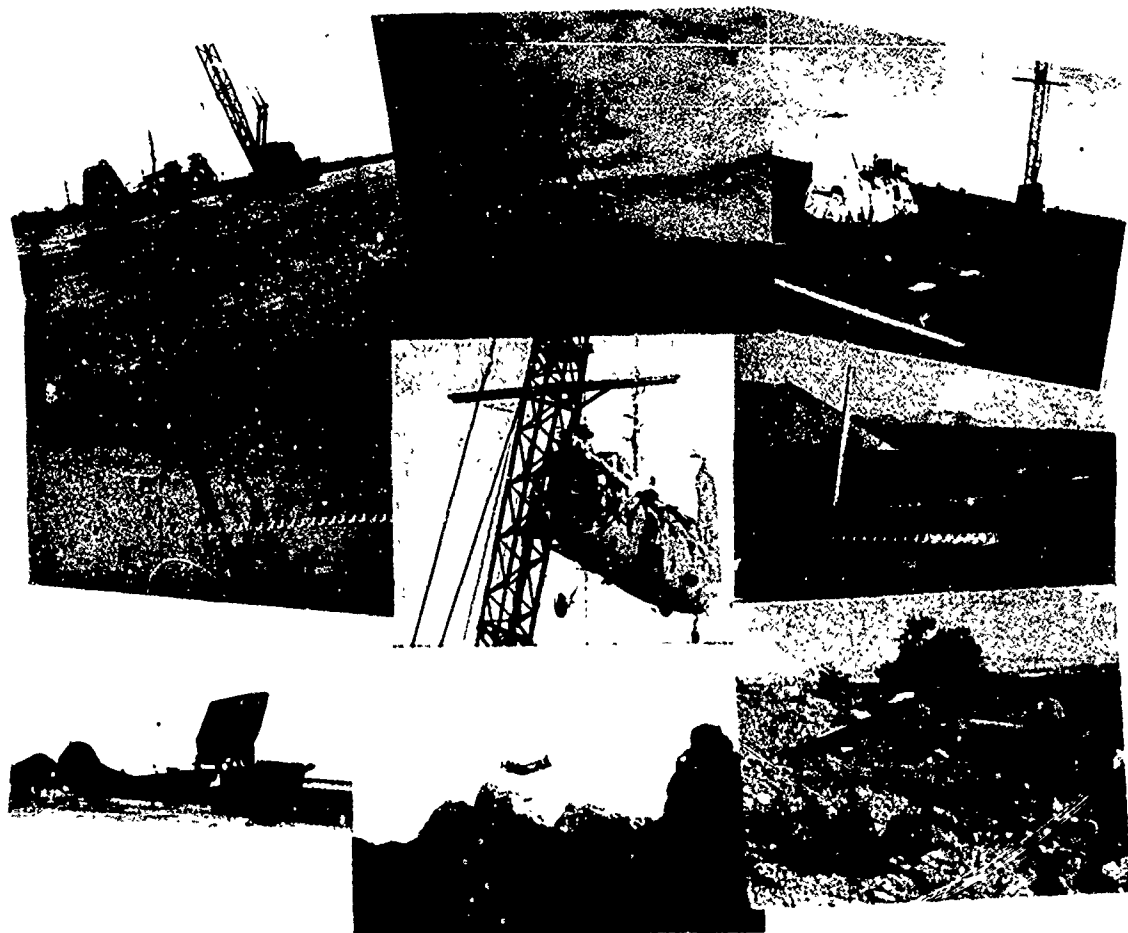
evaluated. Hypotheses regarding the effects on judgments of damage of differences in background stimuli and in the past experience of the rater will be tested.

This study will follow after No. 7, Development of an Aircraft Damage Rating Scale.

EXPERIMENTAL RESEARCH (CRASH TESTING)

Two full-scale tests were conducted under the terms of this contract:

- (1) An instrumented H-25 Piasecki helicopter was dropped from a height of 28 feet from a crane moving along a horizontal runway at 30 miles per hour (22 October 1960);
- (2) An L-19 fixed-wing aircraft was dropped from an H-21 helicopter at a speed of 35 knots and from a height of 40 feet above the terrain.



SECTION VI

PRELIMINARY CONSIDERATIONS

The initial step for the start of an experimental research program involving crash testing of a full-scale aircraft and dynamic testing of aircraft components was to review the work that had been done by a number of agencies over a considerable period of time. In general, these efforts fell into three broad avenues of investigation: (1) human tolerance to acceleration, (2) tolerance of aircraft structure to decelerative forces, and (3) investigation of components by commercial agencies. The results of the work accomplished in these areas over the past years has been extremely beneficial in the improvement of aircraft and components from a crash-safety point of view. However, little or none of the work appears to be directly applicable to rotary wing and other unconventional aircraft such as V/STOL types being utilized or planned for utilization by the Army.

It was concluded, therefore, that if any significant reduction of losses is to be attained with regard to these types of aircraft, it would be necessary to undertake a progressive series of carefully designed full-scale research experiments to investigate and establish the relationship between human tolerance to force and vehicle structure and components as they interact with each other in aircraft accidents involving these types of aircraft and to supplement these full-scale experiments with intermediate stage testing of components and related elements under dynamic conditions.

It also was concluded that the complexity of the problem would require consideration of a long range progressive research program to be developed on



SECTION VI

the basis of experience gained as each experiment was conducted. The methods of testing then could become more elaborate as the program proceeded and could be developed in such a manner that intermediate, less expensive dynamic research facilities would be used for intermediate stage testing of components. Finally, the evaluation of the redesigned components then would be made in subsequent full-scale dynamic tests.

SECTION VI

THE H-25 HELICOPTER DROP TEST

Upon agreement as to the scope and requirements of a long-range dynamic test program, it was decided to initiate the program with a full-scale crash test of an available rotary-wing aircraft.

The following five methods appeared to be feasible and to satisfy the objectives and requirements of the program: (1) Crane Drops, (2) Aerial Tramway Drops, (3) Sled or Incline Releases, (4) Helicopter Drops, and (5) Remote Controlled Drones.

After careful consideration of each of these, it was recommended that the initial drop be made from a running crane.

TRECOM accepted this recommendation and authorized the Flight Safety Foundation, through its AvCIP Division, to proceed with the crash test of an H-25 helicopter subject to appropriate instrumentation and both electronic and photographic recording.

Initiating the Experiment

Early in July 1960, Flight Safety Foundation issued a specification for dynamic testing by crane drop of the H-25 helicopter to sixteen (16) prospective contractors, with a request that proposals be submitted before the last week of July for work involving: (1) preparation of an airborne recording system, (2) instrumentation of the vehicle, and (3) execution of the drop in a manner that would provide data suitable for analysis and interpretation by FSF. Seven (7) proposals were received and evaluated, and a sub-contract was given to Vought



Aeronautics of the Chance-Vought Aircraft Corporation on 1 August 1960.

Summarized here are the steps taken to accomplish the drop, together with a general statement of results. Complete details are given in a Preliminary Report (TREC Technical Report 60-75) and in a Technical Report (TREC Technical Report 60-76). The test also is covered in two sound motion picture films, a documentary version and a technical version.

Preparing for the Test

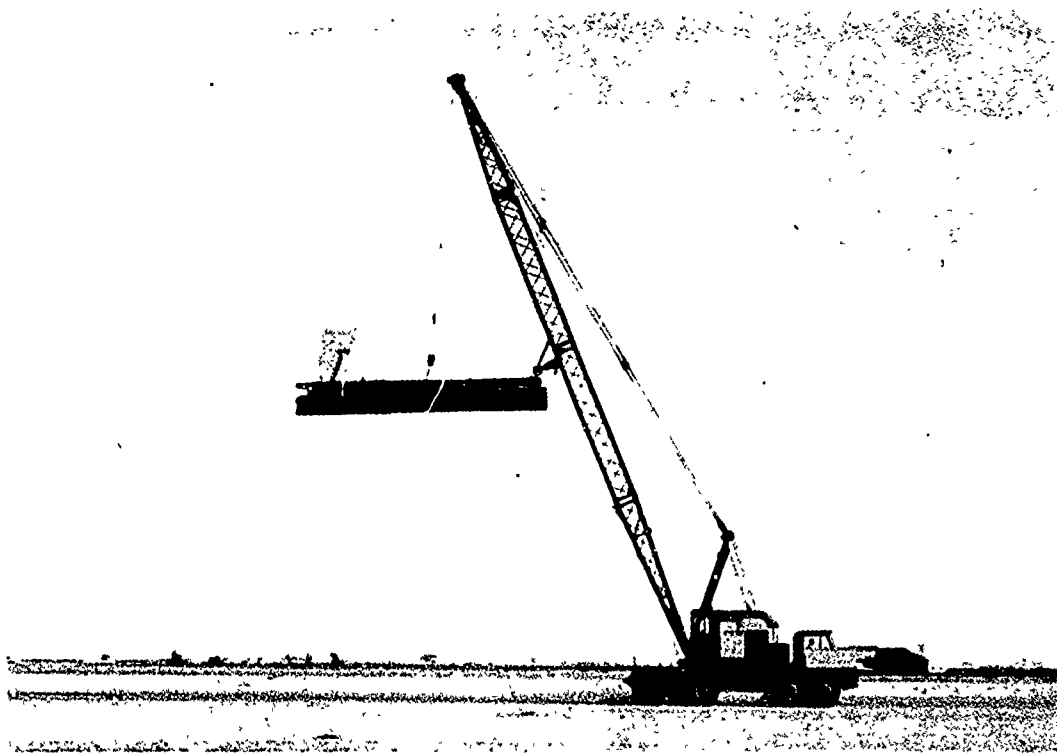
Four (4) major elements first had to be developed in preparation for the actual crash. These were:

- (1) A stabilization system which would permit the helicopter to be held rigidly by the crane and yet released freely;
- (2) An energy-absorbing package to permit use of an airborne recording oscillograph;
- (3) Instrumentation within the helicopter to provide maximum coverage as well as a limited amount of simultaneous recording on both the airborne and ground recording oscillographs; and
- (4) Photographic coverage at high speed (1,000 fps. and 200 fps.), as well as at normal speeds, both internally and externally.

SECTION VI

1. Stabilization System. The suspended helicopter was stabilized in the pitch, yaw, and roll directions during the crane run by means of a fitting, attached to the forward rotor-mount, which slipped into a socket on the crane boom. The fitting was pre-loaded vertically by hoisting the helicopter at a point forward of its center of gravity. Upon release of the helicopter, the fitting was free to slip out of the socket. Sway bracing was also provided between the main release hook and the crane boom to further stabilize the helicopter during the test run.

This system and other phases of the test drop were checked out by means of a simulated drop using a 6,000-pound bundle of logs, as shown below.





2. Packaging of Airborne Oscillograph. Since proper operation of an airborne oscillograph (including timer and inverter) could not be guaranteed at accelerations exceeding 15G's, it was necessary to shock-mount this equipment. The container designed to house this equipment included styrofoam packing up to 4 inches thick around the equipment to protect it in case of failure of the energy absorption system. Energy absorption devices, capable of reducing the "G" loading on the equipment to the acceptable 15G limit, were designed using Dow styrofoam, density 2 pounds per cubic foot, as the energy absorption material.

Two separate energy absorption devices were installed in the helicopter for the crash tests. The vertical shock device limiting the maximum loading to the electronic package to 12G was mounted externally on top of the helicopter. The longitudinal shock device limiting the maximum loading to the electronic package to 8G was mounted in the helicopter on the shelf above the main fuel cell. The resultant design loading on the electronic package from the simultaneous loading of the two devices was 14.5G.

3. Instrumentation. Instrumentation consisted of installing pickups at a total of sixteen (16) locations and recording the data on independent airborne and ground recording systems. Strain gage type accelerometers were installed to measure vertical, horizontal, and/or lateral accelerations at ten (10) points such as cockpit floor, cabin floor, pilot's seat, cranial cavities of both dummies, etc. Strain gage type tensiometers were used to measure loads at six (6) points such as shoulder harness of pilot dummy, seat belt of

SECTION VI

passenger dummy, etc.

Altogether there were 34 instrumentation pick-ups in the aircraft, recorded on two (2) 18-channel ground and one (1) 26-channel airborne oscillographs. Eight (8) of the channels were simultaneously recorded on both the ground and airborne recorders.

4. Photographic Recording. Internal photographic recording was handled by two (2) high-speed cameras to view the cockpit area, two (2) high-speed cameras to view the passenger compartment, and two (2) normal-speed gun-sight cameras to provide comparisons with the high-speed cameras.

Externally, there was a battery of cameras ranging from 16 mm. to 70 mm., with speeds ranging from normal to 200 fps. to 1,000 fps.

Executing the Drop

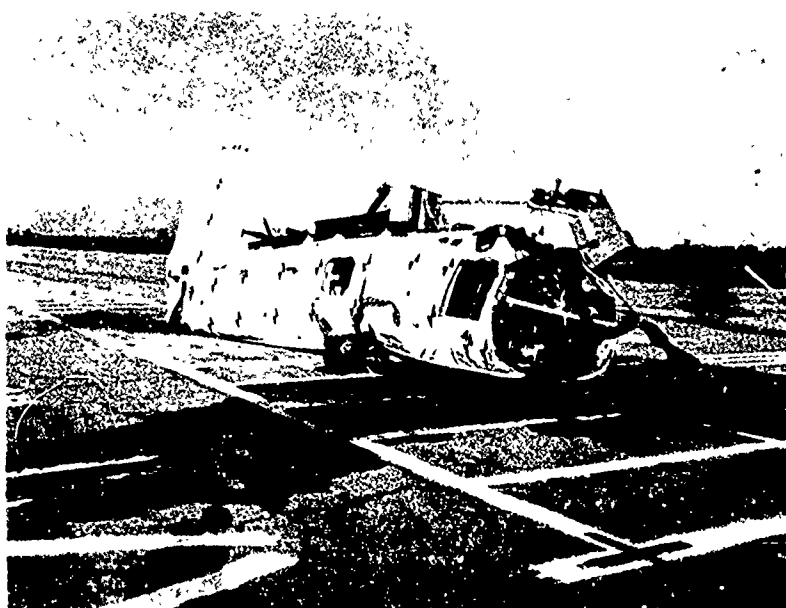
The helicopter, suspended from a 75-foot crane, was dropped from a free-fall height of 28 feet while traveling at a speed of 30 miles per hour after a 4,000-foot run, release being automatic from a triggering device located at a pre-determined point on the ground. In the helicopter were: (1) an anthropomorphic dummy in the left cockpit seat, (2) a similar dummy in the passenger compartment, (3) a Mark XII range extender tank in the right cockpit seat, (4) an airborne oscillograph recording system, and (5) photographic recording equipment.

The center of the helicopter impacted at a point 2 feet to the right and 3 feet forward of target dead center. During the free fall the aircraft was observed to roll slightly to the left and yaw to the right; the roll angle measured

approximately 6 degrees, the yaw angle approximately 5 degrees at ground contact. There was no pitching. The helicopter moved forward a distance of 16 feet after contact.

Before and after photographs are shown below:

Before



After

SECTION VI

Observable Test Results

Results were judged initially on the basis of (1) visual observation of the aircraft and of its components during the drop and at the scene immediately thereafter, (2) check-out of all instrumentation and recording equipment following the drop, and (3) review of all photographic coverage.

Visual observation during and immediately following the crash permitted several general conclusions to be made with respect to structural damage, injury to pilot and passenger, and damage to the range extender tank.

a. Helicopter Structure

At ground contact, the soft fuselage structure was pushed in by the stiffer landing gear, causing considerable distortion to the fuselage around the gear. The outer shell of the helicopter did not greatly distort except on the underside; however, there were a number of skin penetrations and breaks.

b. Pilot

The pilot seat support structure collapsed and the dummy pilot's head struck the fuselage frame on the left hand side of the cockpit violently enough to split his helmet visor. It was evident that very high vertical forces were also encountered by this dummy.

c. Passenger

The troop seat collapsed in such a manner that the passenger dummy was thrown forward and downward, his head contacting the rear of the pilot's seat.

d. Range Extender Tank

The copilot seat support structure failed, causing the seat to move forward. The range extender fuel tank located in this seat contacted the structure causing the cell to rupture with its fuel (colored water) spilling over a large area.

Examination and check-out of all instrumentation and of all recording systems indicated satisfactory performance.

a. Oscillograph Recording System

Examination of both the airborne and the ground instrumentation recording systems following the crash found this equipment to be operable. The shock absorption devices had functioned to properly protect the equipment and allow its operation during the test.

Of special significance was the fact that there were no losses of any oscillograph recordings during impact or during the critical post-crash period; both airborne and ground equipment maintained operation on all 34 channels; moreover, there was no attrition of instrumentation or recording equipment; normally a 20 percent loss may be anticipated but, in this case the loss was zero.

b. Airborne Cameras

All airborne cameras except the two gunsight cameras functioned properly and no damage was suffered. It was found, however,

SECTION VI

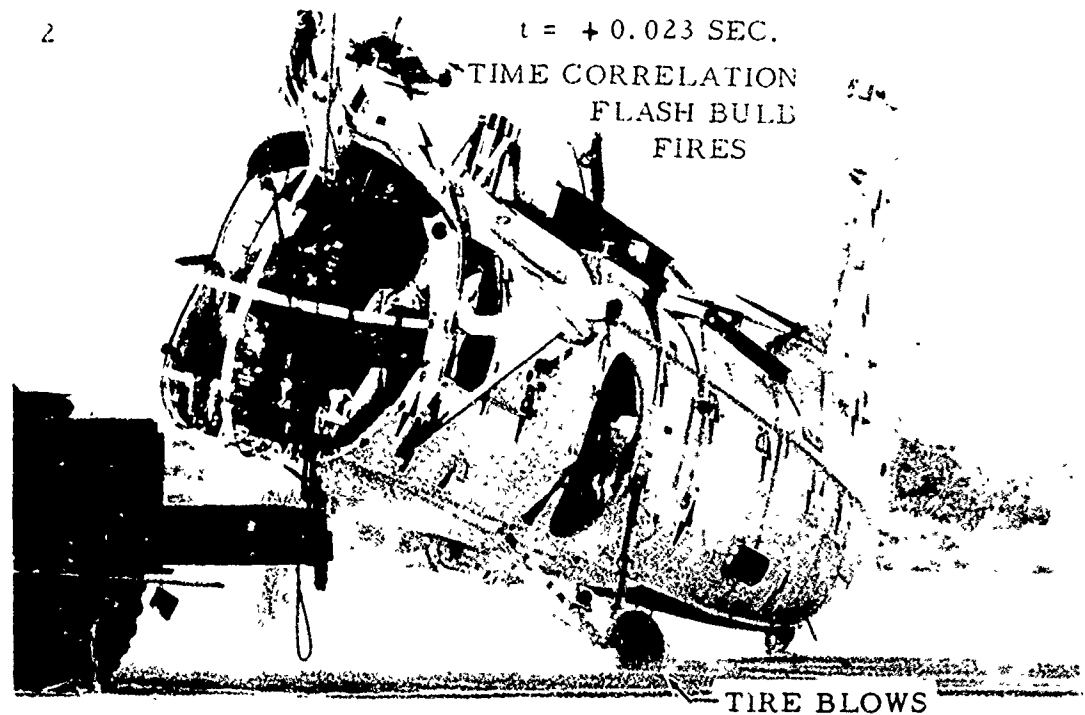
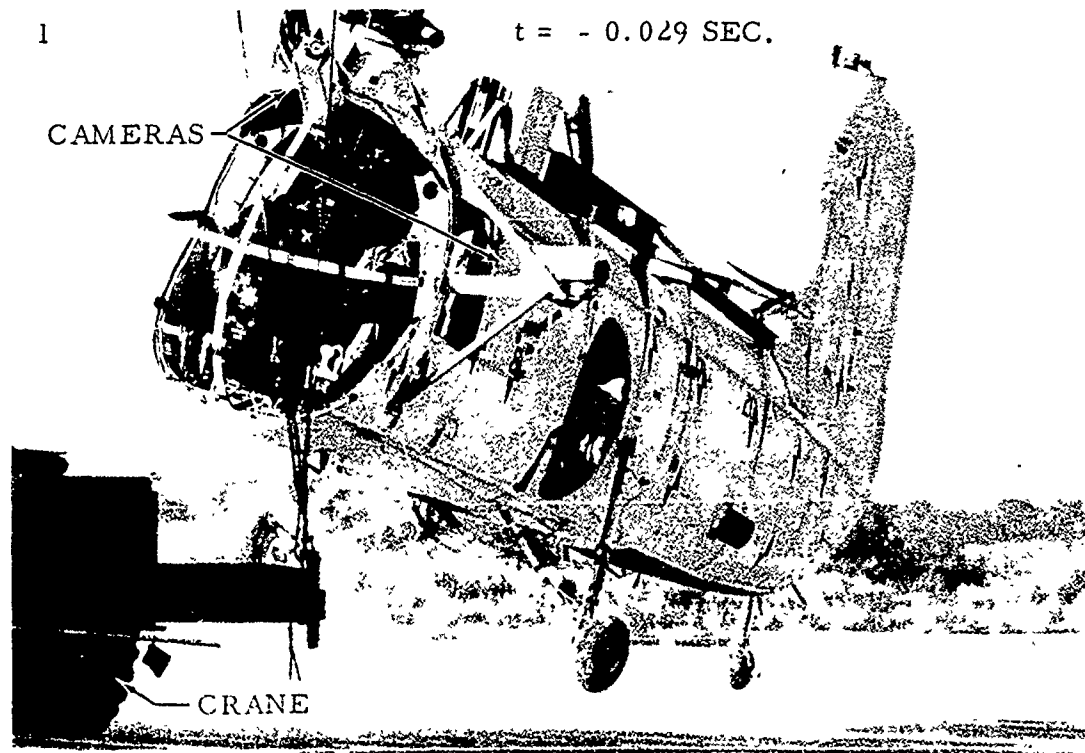
that internal lighting was not completely adequate. Also, the camera mounted opposite the passenger tore loose when the roof collapsed inward and photographic coverage was lost.

c. Ground Cameras

All ground cameras functioned properly and excellent coverage at all three speeds - normal, 200 fps., and 1,000 fps. - was obtained. This was particularly true of the newly-developed high-speed 35 mm. camera provided and operated by personnel of Photo-Sonics, Inc. and of the 70 mm. camera provided and operated by Derwyn M. Severy of the University of California at Los Angeles.

Photographic review provided still additional information as to what actually occurred. Highlights of this are presented on the following pages in a series of sequence photographs taken with the 70 mm. camera at a speed of 24 frames per second. The lapsed time after impact is given for each view.

These and other dynamic actions which took place and which are observable through high-speed photography demonstrate clearly the impossibility of determining with exactness the true dynamics of aircraft accidents from post-crash investigation alone.

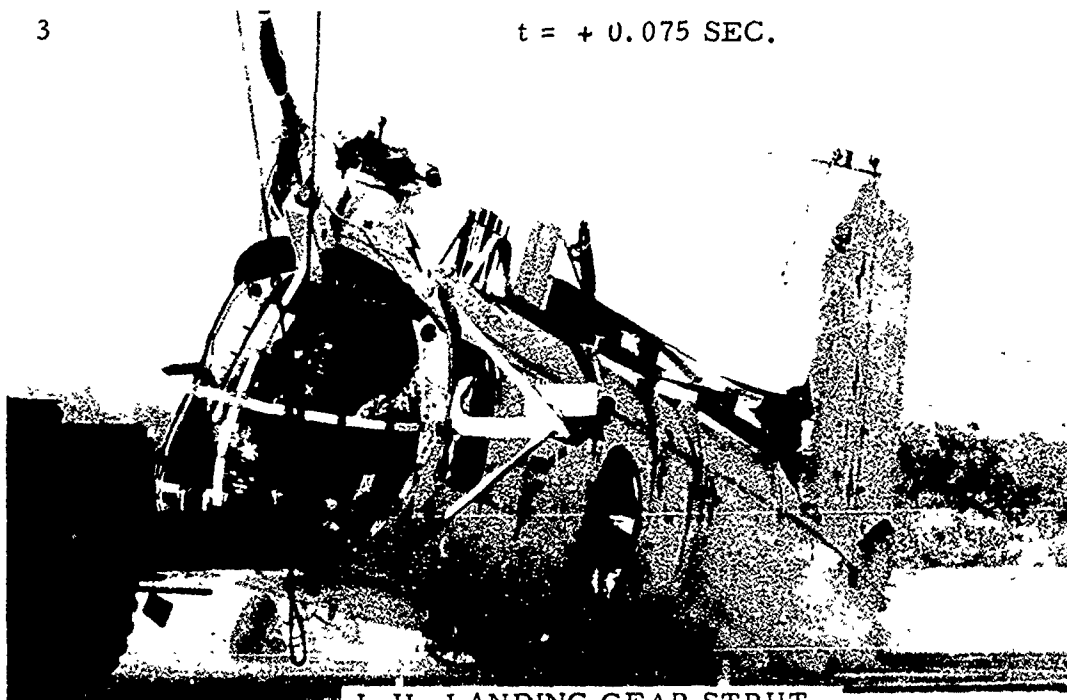


SEQUENCE PHOTOGRAPHS, H-25 DROP TEST

SECTION VI

3

$t = + 0.075 \text{ SEC.}$

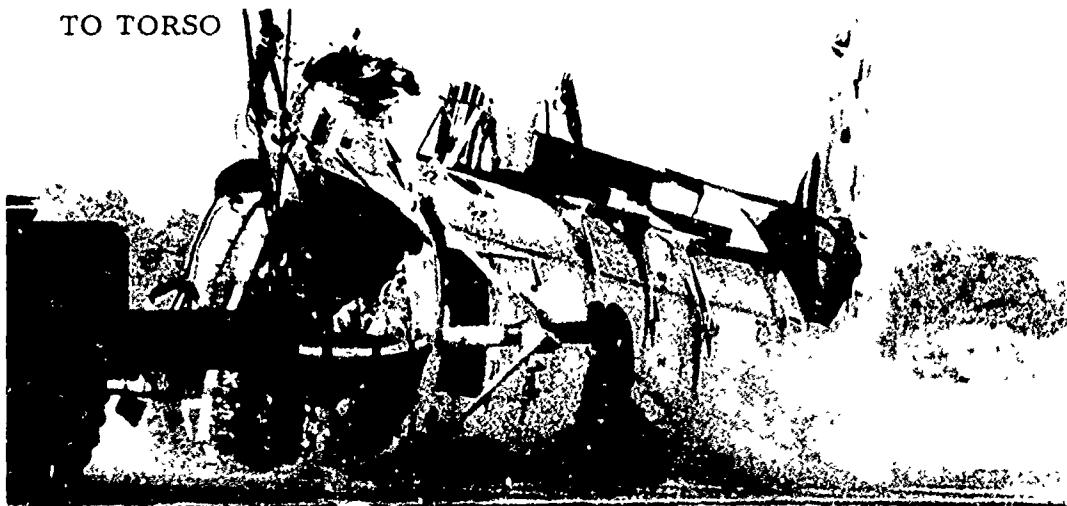


L. H. LANDING GEAR STRUT
PUSHES THROUGH FUSELAGE

4

$t = + 0.127 \text{ SEC.}$

FORWARD UNDER-BELLY BEGINS
TO CRUSH, MOVING PILOT'S KNEES
AND FEET UPWARD WITH RESPECT
TO TORSO

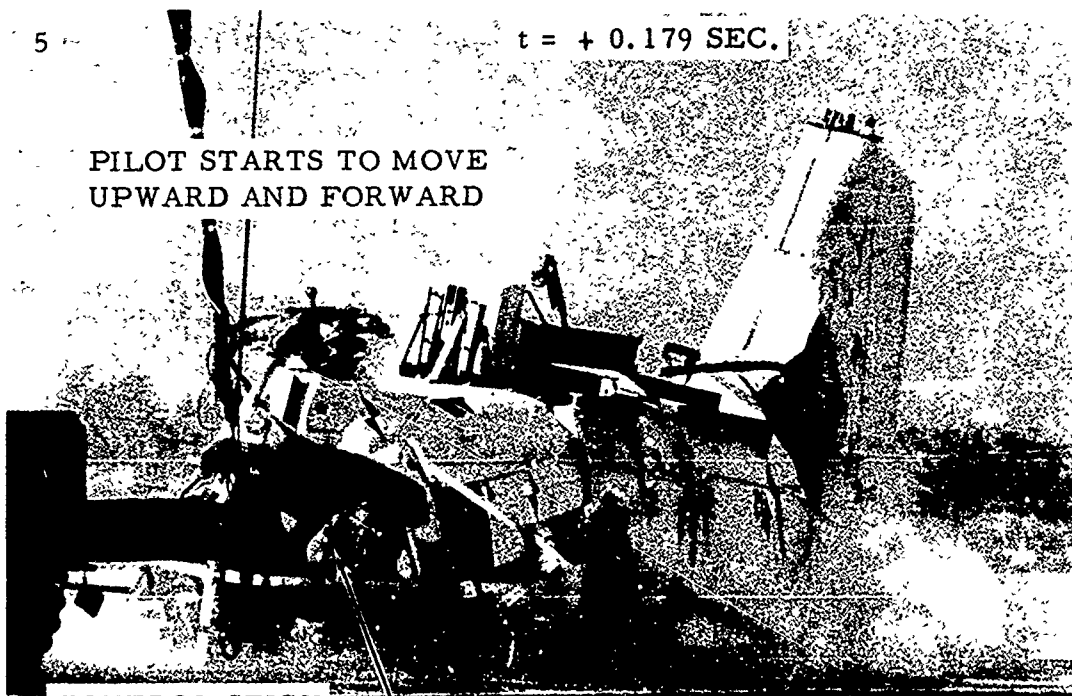


SEQUENCE PHOTOGRAPHS, H-25 DROP TEST

5

$t = + 0.179 \text{ SEC.}$

PILOT STARTS TO MOVE
UPWARD AND FORWARD

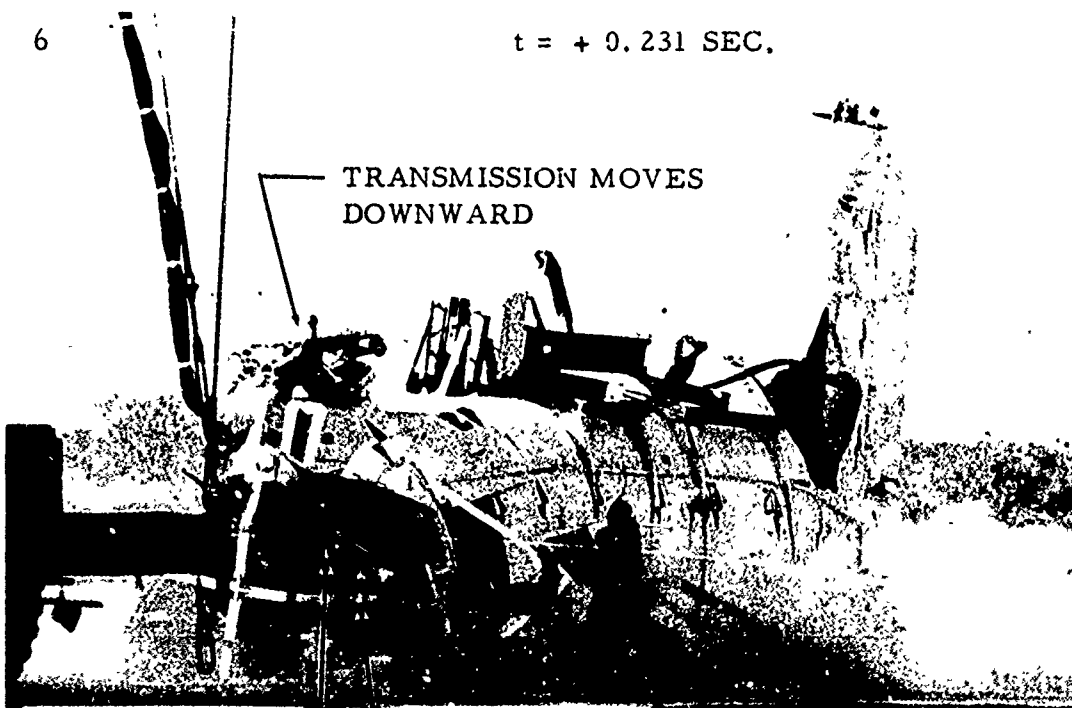


CONTROL STICK

6

$t = + 0.231 \text{ SEC.}$

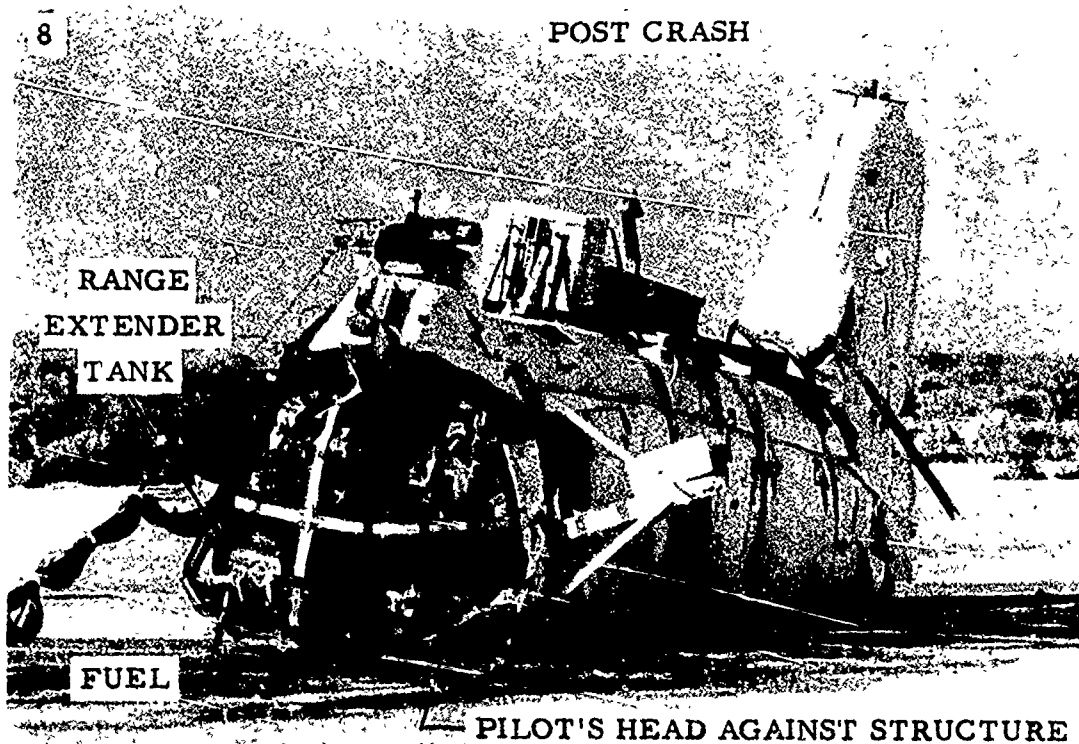
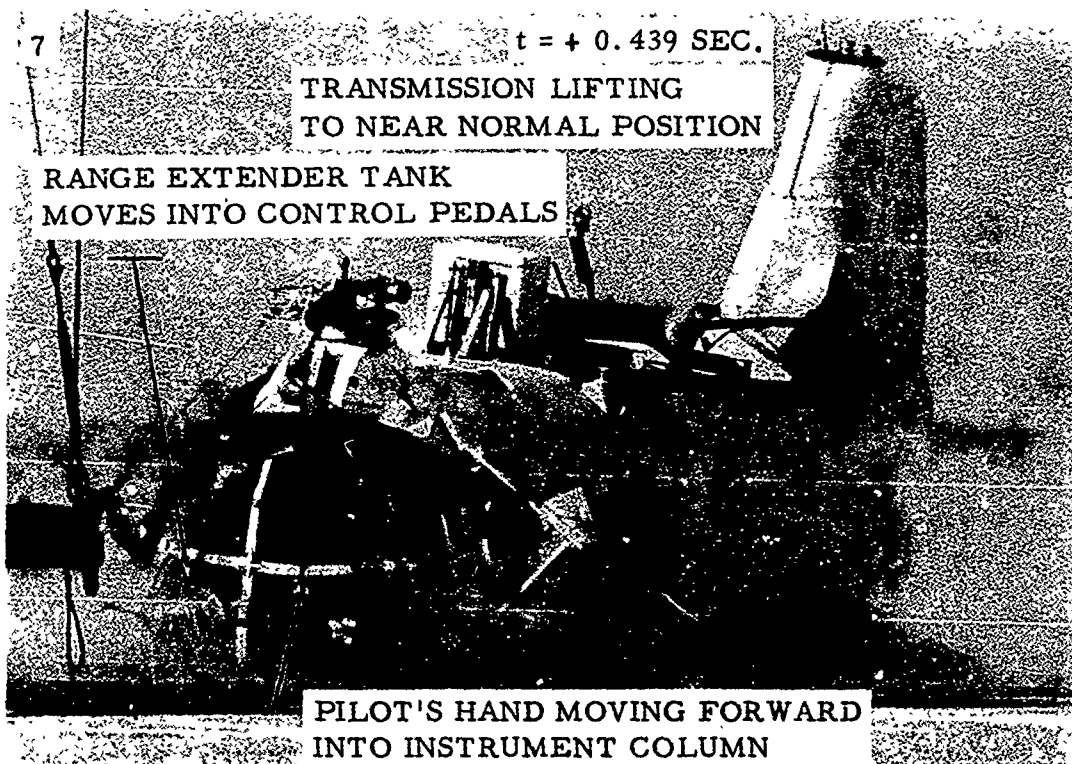
TRANSMISSION MOVES
DOWNWARD



PILOT'S ELBOW - PILOT'S HAND

SEQUENCE PHOTOGRAPHS, H-25 DROP TEST

SECTION VI



SEQUENCE PHOTOGRAPHS, H-25 DROP TEST



SECTION VI

Data Reduction and Interpretation

The reduction and interpretation of the oscillograph data obtained during the H-25 test has been divided into four phases:

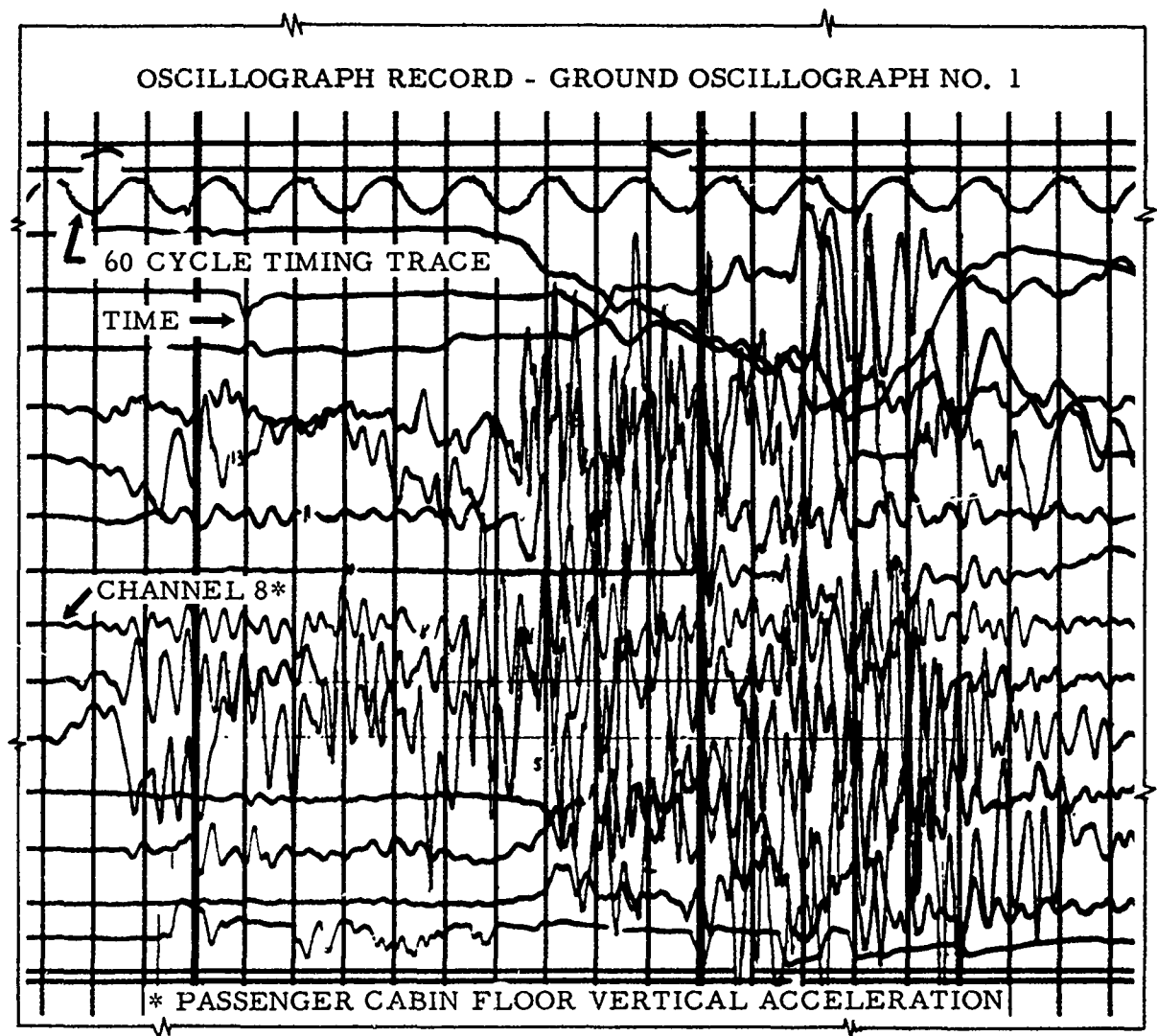
- (1) Transcription of the records;
- (2) Attenuation of the "high frequency" components;
- (3) Validation of the records;
- (4) Analysis, interpretation, and correlation with photographic evidence.

Each of these phases must be considered in conjunction with each of the 42 records obtained (34 end instruments with 8 duplicate records).

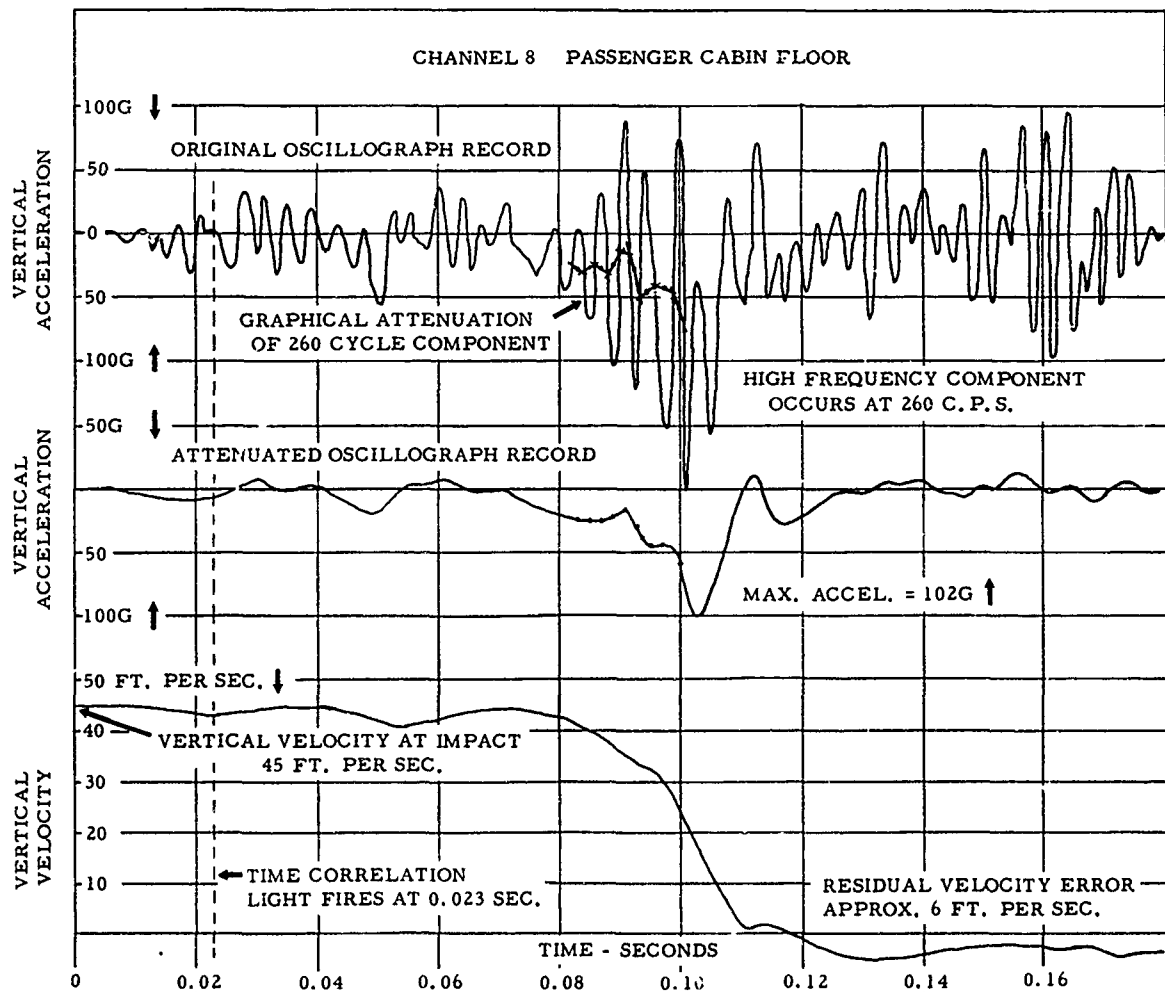
1. Transcription of Records. Because of the number of channels to be recorded and the limited oscillograph paper width, three oscillographs were required for recording the data, with up to 20 channels (plus two reference traces) recorded on one oscillograph.

Three steps in transcribing the resultant data were required: (1) separating the closely spaced records; (2) bringing the records from the three oscillographs to a common time-base; and (3) enlarging the records where necessary to permit accurate evaluation of areas under the acceleration time curves. Fortunately, all records were of excellent quality, greatly simplifying the separation of the individual traces. A partial section of one original oscillograph records is shown on the following page.

SECTION VI



Channel 8, vertical acceleration of the passenger cabin floor, has been extracted from the above record, and is shown on the following page. A 3X magnification of this trace was used in obtaining the attenuated acceleration curve and the velocity curve.



2. Attenuation of the High Frequency Components. In acceleration measurements of complex structures, "ringing", or the introduction of various natural frequencies of the structure into the acceleration records, is a constant problem. Often "high frequency components" of very large magnitude are observed. This occurs because of the inherent relation

SECTION VI

between displacement, acceleration, and frequency in sinusoidal oscillations.

To illustrate:

If a point is moving harmonically with displacement "X", given by the equation:

$$X = A \sin \omega t$$

then the acceleration of the point is:

$$a = -\omega^2 A \sin \omega t = -4\pi^2 f^2 A \sin \omega t$$

Where:

A = The amplitude of the oscillation

ω = Circular frequency in radians per sec.

$$f = \frac{\omega}{2\pi} = \text{frequency in cycles per sec.}$$

Thus, "a" can be very large even though "A" is small for large values of "f". For the oscillograph record shown, the 260 c. p. s. component gives an acceleration amplitude of 100 G for an oscillation with an amplitude of only 0.0145 inch. These high frequency peaks are probably meaningless insofar as inducing possible injury to an occupant of the aircraft, and have been graphically attenuated from the final acceleration-time plot as shown in the attenuated oscillograph record.

3. Validation of the Records. The foregoing method of smoothing the data requires some judgment on the part of the analyst, introducing a possible source of error. However, certain steps can be taken to further check the validity of the final results as follows.

The acceleration-time curves obtained in the test can be integrated and



SECTION VI

compared with the known change in velocity (or displacement) of the point to which the transducer was attached. For example, from the definition of acceleration:

$$\frac{dv}{dt} = a$$

It follows that:

$$V_2 - V_1 = \int_{V_1}^{V_2} dv = \int_{t_1}^{t_2} a \cdot dt$$

This means that the area under the acceleration-time curve must be equal to the change in velocity.

For the passenger cabin floor vertical acceleration, the vertical velocity at impact, as obtained from measurements of photographs, was 45 feet per second. This agrees satisfactorily with a computed value of 42.5 feet per second. The integrated acceleration-time curve gives the velocity curve shown at the bottom of the graph. A residual velocity error of about 6 feet per second or about 13 percent of the initial impact velocity of 45 feet per second is seen to exist. This is well within the overall expected tolerance for dynamic measurements of the complexity encountered of this test. It represents an average error for the 0.18 sec. impact duration of 1 G or 1% of the peak value recorded.

The force-time curves obtained with tensiometers installed in seat belts and shoulder harnesses only can be partially checked. The method requires a comparison of the computed accelerations, based on the measured belt forces and restraint-subject masses, with the accelerations measured

SECTION VI

within the subject. Only an approximate order of magnitude can be so obtained because of certain unknown forces (from seat pan, rudder pedals, etc.) and the lack of rigidity of the mass of the dummy occupants.

4. Analysis and Interpretation. Correlation of two or more acceleration or force-time historys, or particularly of photographs with the various time historys, are providing excellent means of analyzing and interpreting the results of this test. Referring to the sequence photo No. 1 and to the attenuated acceleration-time curve, it will be observed that at 0.23 seconds (tire blowing) the LH gear has not appreciably decelerated the passenger compartment floor. At 0.05 seconds, with both gears on the ground (photo not shown), an upward acceleration of 20 G is recorded. This drops off at 0.06 seconds, both gears having failed at their attach points. At 0.075 (photo No. 3) the compartment floor is contacting the ground and the acceleration begins to rise, peaking at 102 G at 0.102 seconds. At 0.127 seconds the cabin floor has been arrested and from this time onward only random oscillations in the structure occur to move the acceleration-time curve from the zero position. Much later, at 0.179 and 0.231 seconds, the transmission begins to lower and the pilot is thrown upward and forward.

At 0.439 seconds (photo No. 7) the transmission is returning to a near normal position. The pilot and range extender tank are still moving forward, with the front of the range extender tank approaching the control pedals. Much of this forward shift of the pilot and the tank were due to the buckling



SECTION VI

of the seat legs. Photograph No. 8 was taken approximately one minute after all motion of the aircraft had ceased.

All oscillograph records are being analyzed in the manner described above and, upon final evaluation and correlation with photographic and other evidence, will be presented in appropriate technical publications.

SECTION VI

THE L-19 DROP TEST

During the contract period, a non-flyable, partially damaged L-19 aircraft was provided to the project for possible use in the simulation of an accident for field training of military crash injury investigators. Training aids used for this purpose generally are wrecked aircraft positioned on the National Guard Papago Park reservation in a manner that simulates the terrain conditions under which the various aircraft actually crashed.

Since it would be necessary to deposit this aircraft in a crashed condition, its availability made it possible to experiment with a helicopter drop or crash test technique. Thus, two objectives were accomplished:

- (1) A light-plane, fixed-wing aircraft accident was simulated in a manner and at a location to contribute to the training of military personnel in crash injury accident investigations; and
- (2) The feasibility of crashing aircraft by suspension and drop from a helicopter was tested with particular value coming from the development of a suspension design, a stabilization technique and a release system.



SECTION VI

The manner in which the drop was planned and carried out is described as follows:

- (1) The aircraft would be suspended from an H-21 helicopter. A special sling which provided excellent stability was designed and fabricated by AvCIR. The helicopter was provided by Fort Huachuca.



- (2) The aircraft was to be dropped from a height of 60 feet at a forward flight speed of 35 knots. This was to simulate a straight ahead stall condition



with an attempt to recover at low altitude. The actual drop was made at 35 knots, but the altitude was approximately 40 feet instead of 60 feet above the terrain.

- (3) Impact was to be on a relatively level terrain with the impact angle being 30 degrees nose down with no roll or yaw. Due to the low altitude at actual drop (40 feet) and a slightly

SECTION VI

premature release, the aircraft impacted against the side of a ravine just ahead of the level terrain selected for the impact area.



This made an impact angle of 60 degrees with reference to the terrain (aircraft nose down 30 degrees and impact slope 30 degrees).

The drop was conducted at 1600 hours on the afternoon of 16 November 1960. The wrecked aircraft now is available as a training aid for crash injury investigation and the feasibility of crash testing by a drop from a helicopter has been checked.

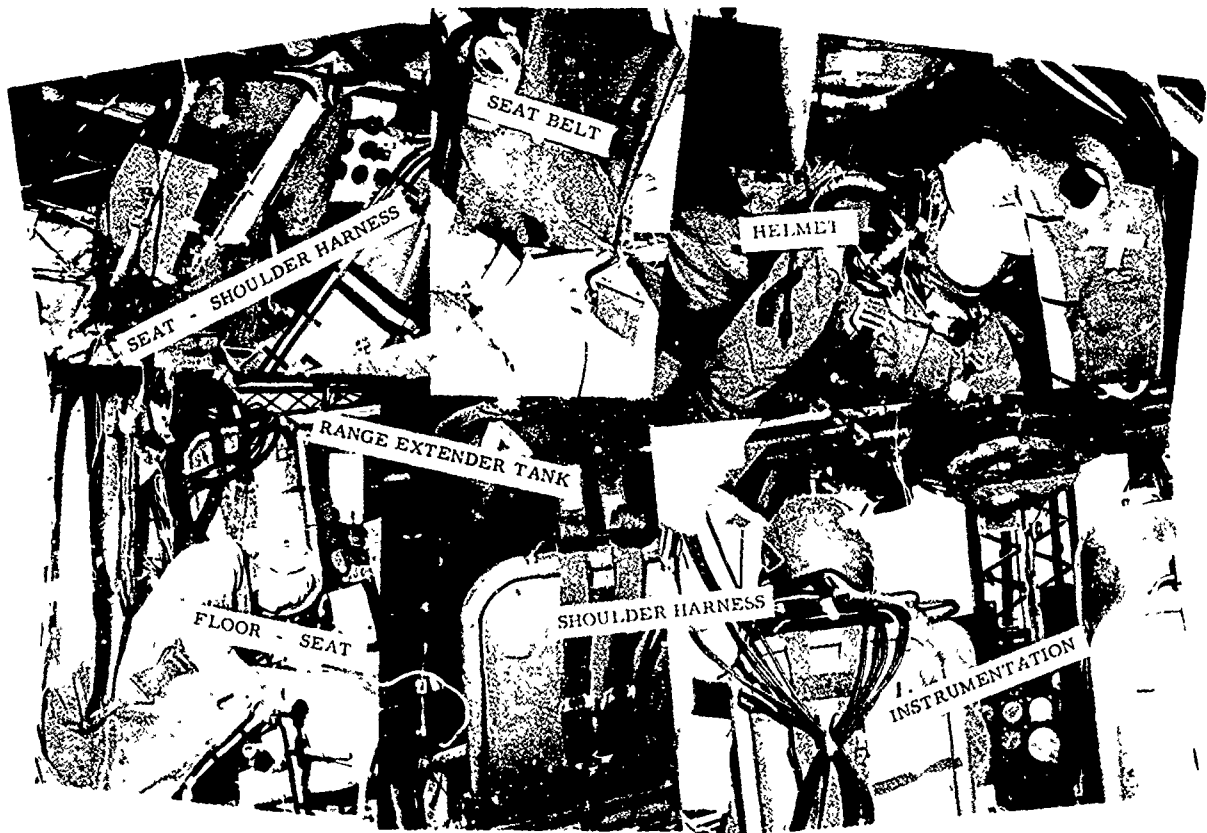


SECTION VII

DYNAMIC TESTING OF SAFETY DEVICES

During the full-scale crash tests described in Section VI, various components such as seat belts, shoulder harness, seat anchorage, a range extender tank, etc. were instrumented to obtain pertinent measurements. Results from the testing of these items are reported upon fully in a Technical Report.

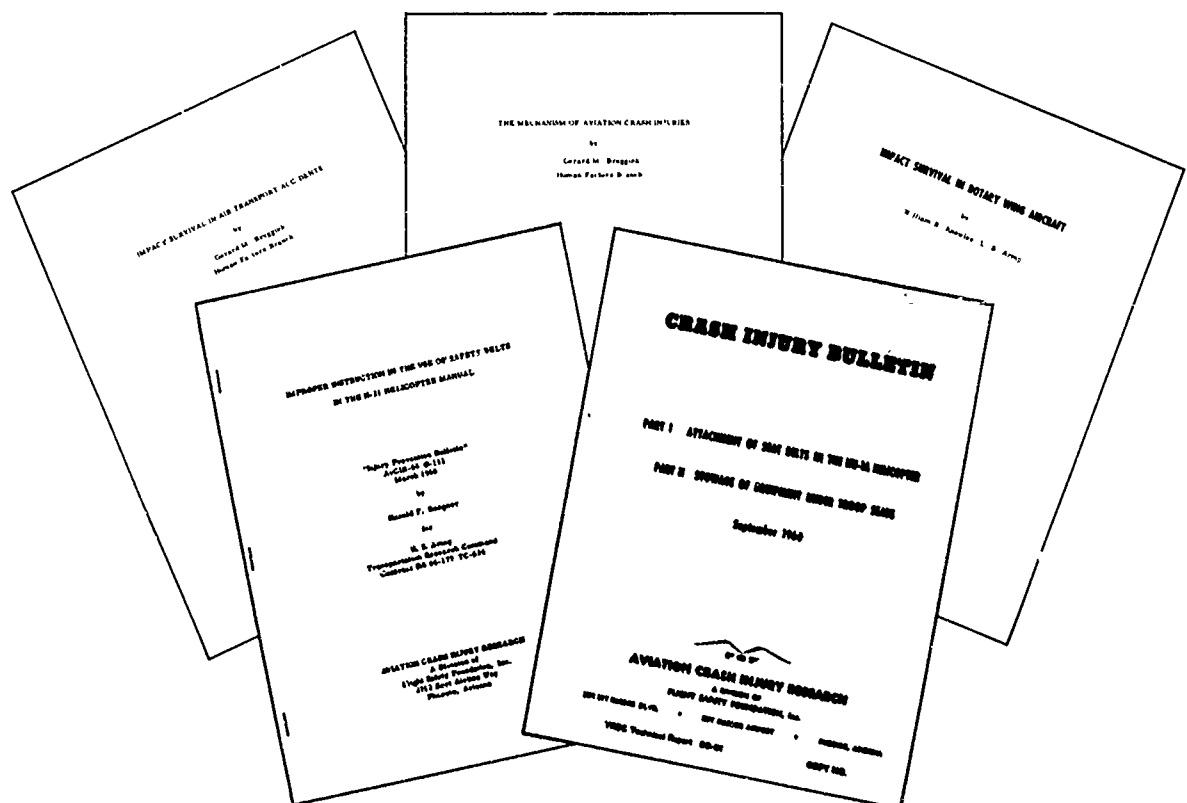
Investigation also was carried on in connection with Experimental Research Program with respect to test facilities available from governmental and commercial sources which would be suitable for the dynamic testing of aircraft components and accessories.





MISCELLANEOUS CRASH INJURY RESEARCH

During the contract period, a number of studies were made which do not specifically relate to any of the previous paragraphs in the Statement of Work; however, all of the studies relate to Aviation Crash Injury Research. Several of the studies resulted in Crash Injury Bulletins to the Army and others were presented as technical papers at symposiums, seminars, and conferences.



SECTION VIII

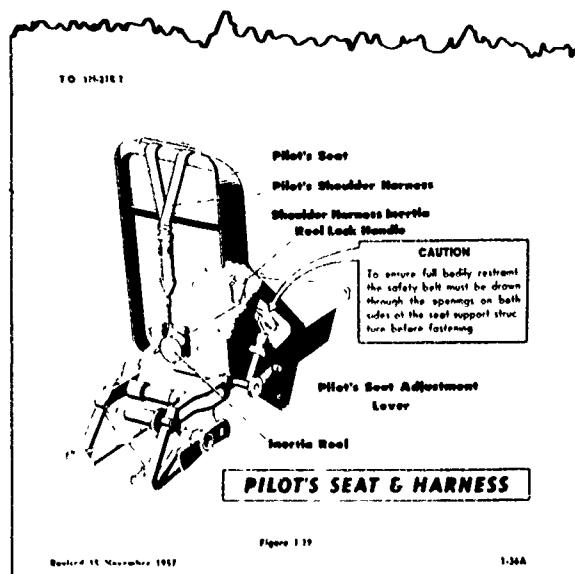
Crash Injury Bulletin

Improper Instruction in the Use of Safety Belts in H-21 Helicopter Manual

During an investigation of an accident involving an H-21 helicopter in which one crew member in the cockpit was fatally injured, it was noticed that the safety belt was improperly positioned on both seats.

In the medical report of this accident, and in one other H-21 accident on file at AvCIR, the medical investigators called attention to positioning of the safety belts as being a probable source of rib-cage and internal injuries.

The AvCIR accident investigation, plus the medical doctors' comments, led to an examination of the Technical Manual covering the safety belt installation. It was found that a 15 November 1957 revision carried a caution note on the proper installation of the belts and a subsequent revision (1 February 1959) deleted the caution note and illustrated



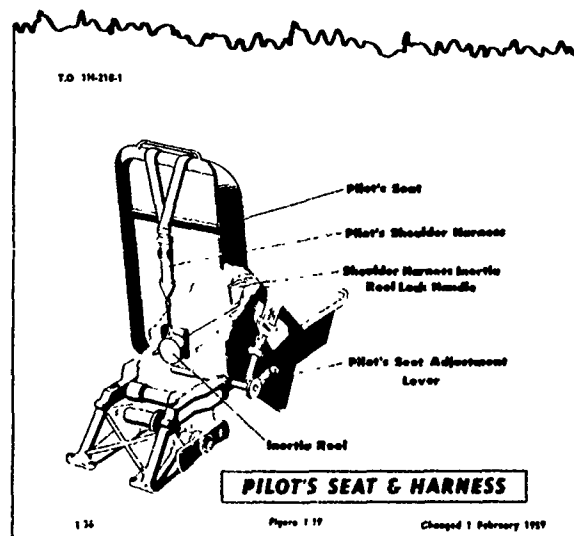
an improper installation.



SECTION VIII

The preceding information was presented in a Crash Injury Prevention Bulletin with a recommendation that the discrepancy be brought to the attention of all units utilizing H-21 helicopters and that the Technical Manual be revised to eliminate the discrepancy.

(Reference: TREC CRD 760 - March 1960; AvCIR 65-O-111)

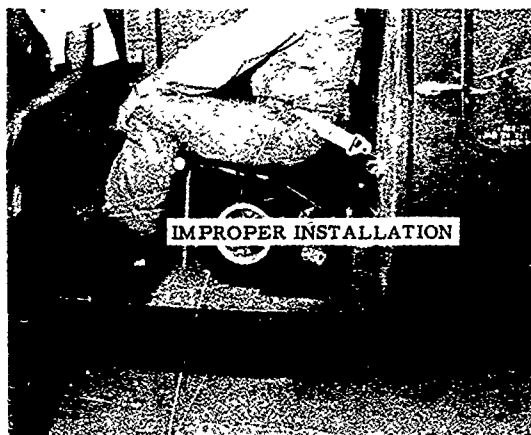


SECTION VIII

Crash Injury Bulletin

Part I - Attachment of Seat Belts in the HU-1A Helicopter

Part II - Stowage of Equipment under Troop Seats



During investigations of several HU-1A accidents, it was noted that the safety belts utilized by occupants of the troop seat of this aircraft were anchored to the rear seat support member rather than to the cables provided in the aircraft for this purpose.

Anchoring of the seat belts to the rear seat support member causes the belt to ride across the occupant at an undesirable angle and introduces a potential cause of internal injuries. Further, this attachment does not have the seat belt anchor strength obtained when the belts are attached to the cables provided, which are anchored to basic aircraft structure.

Part I of this bulletin recommended that the units operating this aircraft be instructed to attach the troop seat belts to the cables provided in the aircraft.

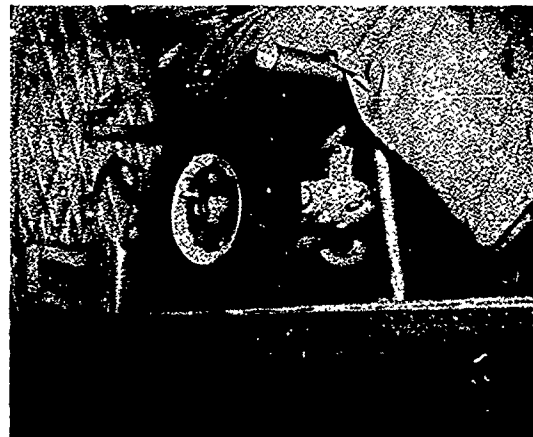




SECTION VIII

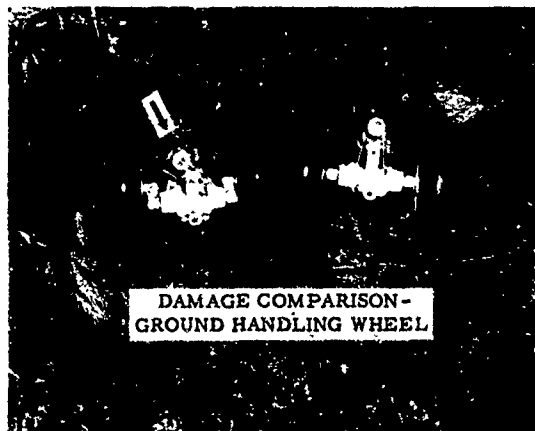
Part II of the bulletin discussed and illustrated the manner in which certain items of loose equipment were stored under the troop seat during operation of the aircraft.

This information resulted from the investigation of an accident in



which one occupant of the troop seat was seriously injured when the troop

seat failed and the occupant bottomed out on a set of ground handling wheels stowed beneath his seat.



It was recommended that the area beneath the troop seats be kept free of loose equipment, and if non-rigid equipment is stored underneath the

seat that it be securely anchored to prevent its being thrown through the aircraft in the event of an accident.

(Reference: TREC Report 60-61, November 1960; AvCIR-69-O-120)

SECTION VIII

Impact Survival in Rotary Wing Military Aircraft

(A paper presented before the 16th Annual National Forum of American Helicopter Society - May 13, 1960)

Injury causation factors regarding dangerous and fatal injuries sustained by crew members and passengers involved in survivable type helicopter accidents are discussed. Crash survival design criteria are reviewed along with specific recommendations for integrating such criteria into the overall design of new rotary wing aircraft. Photographs of survivable type helicopter accidents are included, each depicting a design feature which has proven to be an injury causation factor. Finally, it is shown how engineering design can decrease the exposure of occupants to dangerous or fatal injuries in future survivable accidents.

The paper was presented by Captain William R. Knowles, MSC, while assigned to Aviation Crash Injury Research.



SECTION VIII

Medical Officer's Role in the Crash Injury Prevention Program

(A paper presented at the Army Aeromedical Symposium, June 7-8, 1960,
Pensacola, Florida)

The purpose of this paper was to acquaint U. S. Army medical doctors and flight surgeons with the crash injury mechanism in U. S. Army aircraft accidents.

The material obtained in actual crash injury investigations of Army aircraft accidents was used to demonstrate the principles of occupant protection in military aircraft with the emphasis on the proper use of available restraint systems and protective equipment.

This paper was subsequently published in "Aeromedical Memo" (September 1960) by the Human Factors Section of the United States Army Board for Aviation Accident Research, Fort Rucker, Alabama.

SECTION VIII

The Mechanism of Aviation Crash Injuries

(A paper presented at the Second International Meeting on Forensic Pathology and Medicine at the New York University Medical Center 18-23 September 1960)

The purpose of this paper was to give forensic pathologists a better understanding of the crash injury mechanism in aircraft accidents which, in turn, will lead to more meaningful medical data from accident investigations.

Some of the subjects discussed in this presentation were: acceleration and G units, crash forces and their effects on aircraft structure, interpretation of wreckage, human G tolerance, internal injuries, spinal injuries, and autopsies.

It was shown that the basic activities in a crash injury prevention program are centered upon the following question: "Were the injuries an inevitable result of the circumstances or could they be attributed to controllable factors such as lack of crashworthiness, inadequate occupant restraint, injurious environment, or inadequate escape provisions?"

This paper has been submitted for publication in the American Journal of Public Health.



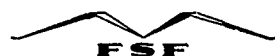
Impact Survival in Air Transport Accidents

(A paper presented at the 13th Annual International Air Safety Seminar, of the Flight Safety Foundation, November 14-18, 1960, Chandler Arizona)

The purpose of this paper was to demonstrate the effect of occupant restraint and occupant environment on impact survival in transport accidents. The study was based on an analysis of three transport accidents involving relatively modern 4-engine transports: the Braniff DC-7C accident, 25 March 1958 at Miami, Florida; the American Airlines Lockheed Electra accident, 3 February 1959, at La Guardia Airport, New York; the Eastern Airlines Lockheed Electra accident, 4 October 1960, at Logan Airport, Boston, Massachusetts.

The results of this study demonstrated the inconsistency between the crash resistance of modern transport fuselage structure and the current occupant protection criteria. The logical conclusion is to revise these criteria in order to improve the chances of impact survival in transport accidents.

This paper is presently being adapted for publication and dissemination by the Flight Safety Foundation, Inc.

FIELD INVESTIGATION OF CIVILIAN ACCIDENTS

In addition to field investigation of certain U. S. Army aircraft accidents, Aviation Crash Injury Research staff investigate most major air transport accidents where survival in spite of severe crash forces has been possible. They also investigate lightplane accidents when the location is reasonably accessible or the crash safety aspects of the accident would appear to be of special interest.

The accidents listed below and described in the pages that follow are those investigated during the contract period although outside the framework of the contract.

Lockheed Electra Accident
La Guardia Airport
New York City, New York
Investigation: 4-20 Feb. 1959

Lockheed Electra Accident
Logan Airport
Boston, Massachusetts
Investigation: 6-14 October 1960

Cessna 182 Accident
Morristown, Arizona
Investigation: 22 March 1960

Aeronca Accident
Apache Junction, Arizona
Investigation: 4 December 1960

Cessna 182 Accident
Pica, Arizona
Investigation: 25 March 1960

Luscombe 8F Accident
Glendale, Arizona
Investigation: 6 December 1960

Stearman Accident
Phoenix, Arizona
Investigation: 10 July 1960

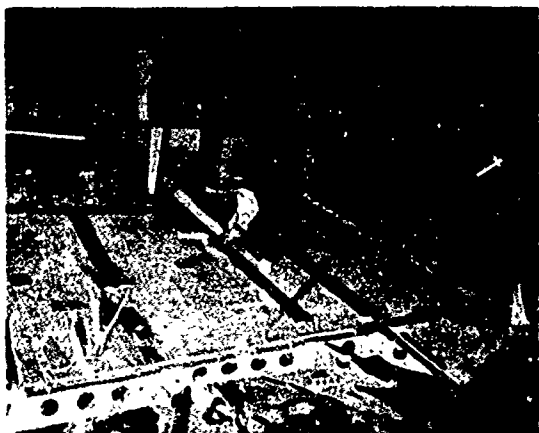
Piper PA-18 Accident
40 miles north of Phoenix, Ariz.
Investigation: 10 December 1960

APPENDIX A

L-188
LOCKHEED ELECTRA ACCIDENT
LA GUARDIA AIRPORT
NEW YORK CITY, NEW YORK
3 FEBRUARY 1959

During a night instrument approach, a Lockheed Electra L-188 was inadvertently flown into the water. The lower forward fuselage belly was completely destroyed by the water impact while the fuselage shell above the floorline was broken into four sections. Only the cockpit shell and the aft fuselage section remained relatively intact. Six of the eight survivors were located in these areas. Sixty-five occupants did not survive the accident.

The full cooperation of the medical authorities involved made it possible to determine the effects of occupant environment on impact survival. The overall injury pattern indicated that, contrary to past experience, chest injuries were a more important death-producing factor than head injuries. It was concluded that this was the combined result of increased head protection by non-injurious seat back characteristics and the presence of a solid chest-impact area near the junction of the seat back and the seat frame.



This accident clearly illustrated the limitations of a restraint system which allows the passenger to come into violent contact with his immediate environment.



APPENDIX A



Other points of interest brought forward during the crash injury investigation were:

1. The survival of some of the lounge occupants could be attributed, in part, to the effectiveness of an emergency exit light which assisted in evacuation;
2. Seat belt end-fittings should be self-aligning and controls are needed to guarantee that they cannot be installed incorrectly;
3. Seat belts should be anchored to primary seat structure which is not affected by failure of arm rests or seat backs; and
4. Service trays inserted in seat back pockets can offset other well-designed, non-injurious features of seat backs.

The results of this investigation have been made available to and discussed with aircraft manufacturers, seat manufacturers, and operators. Details of the investigation also are being used in a more comprehensive study of crash survival in transport accidents with a report currently in preparation.

APPENDIX A

CESSNA 182 ACCIDENT MORRISTOWN, ARIZONA 21 MARCH 1960

A Cessna 182 aircraft, with pilot and one passenger, crashed while attempting a landing on a privately owned landing strip located in a box canyon near Morristown, Arizona.



The open or "approach" end of the canyon is spanned by high tension wires which were contacted by the aircraft. When the aircraft contacted the wires, it rolled to the left approximately 160 degrees and impacted on the runway in an inverted attitude. The aircraft slid and bounced approximately 50 feet from initial impact. (It is interesting to note that five (5) accidents have occurred at this same location, all caused by the high tension wires spanning the approach end of the canyon.)

The aircraft was completely demolished. The pilot suffered a deep laceration from the edge of the left eye to the left ear. The passenger suffered two deep lacerations running from the forehead to the top of the head, a puncture wound in the left anterior tibia area, and a torn lip.

From an analysis of the injuries experienced and the damage to the aircraft, it was concluded that the injuries could have been prevented by the use of shoulder harnesses.

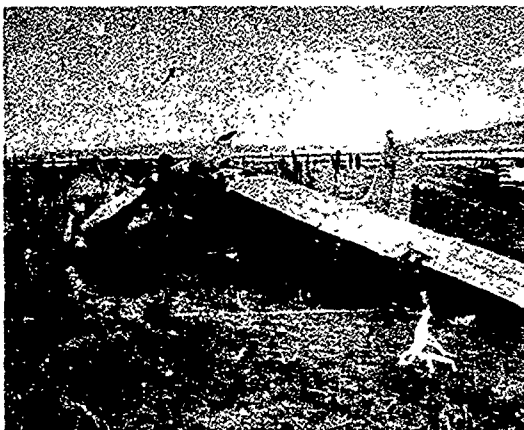


APPENDIX A

The detailed findings of this accident have been discussed with the manufacturer of the aircraft and also will be used in crash survival studies involving light fixed-wing aircraft.

APPENDIX A

CESSNA 182 ACCIDENT PICA, ARIZONA 24 MARCH 1960



A Cessna 182 aircraft crashed during take-off at 4:25 p.m., 24 March 1960 in the Santa Fe Stockyards at Pica, Arizona.

The aircraft was utilizing a rough dirt road for take-off during gusty wind conditions. Thunderstorms

were in the area. After becoming airborne and reaching approximately 100 feet, the aircraft appeared to settle and struck the iron rack on a pick-up truck parked in front of the corral. On impact with the truck, the right gear was torn free. Immediately thereafter, contact was made with a 12-inch square corral gate post, tearing off the right wing strut and the right horizontal stabilizer and elevator. As the right wing was tearing free, the aircraft continued across the corral and struck nose down in soft terrain.

The only occupant on board, the pilot, died of multiple injuries to the head, chest, abdomen, hips, and legs along with severe shock and loss of blood. A contributing factor to the fatality was the delay involved in extricating the pilot from the wreckage and in transportation to the hospital.

The detailed findings of this accident have been discussed with the aircraft manufacturer and also will be used in general crash survival studies of light fixed-wing aircraft.



APPENDIX A

STEARMAN ACCIDENT PHOENIX, ARIZONA 10 JULY 1960

A Stearman agriculture-type aircraft crashed during take-off in the dry river bed at Phoenix, Arizona at 5:30 A.M. on 10 July 1960.

At 100 to 200 feet of altitude following take-off, the aircraft, loaded with insecticides, experienced a power failure necessitating a forced landing.

The aircraft settled down in a normal landing attitude, striking a pile of large rocks, sliding for approximately 60 feet, nosing over, and then sliding an additional 17 feet inverted. The aircraft was demolished.



The pilot was uninjured with the exception of being covered with toxic materials. However, the insecticide was not of the Parathion or Malathion type where fatality would have been certain.

Investigation revealed that the pilot had been wearing a crash helmet, shoulder harness, and safety belt, the combination of which is believed to be the life saving factor in this accident.

The detailed findings of this accident will be used in crash survival studies involving light fixed-wing aircraft.

APPENDIX A

LOCKHEED ELECTRA ACCIDENT LOGAN AIRPORT BOSTON, MASSACHUSETTS 4 OCTOBER 1960

Immediately after take-off, a Lockheed Electra L-188 struck a water surface in a near-vertical attitude. The forward and center fuselage sections were completely destroyed. The tail section, which included the lounge and part of the main cabin, remained remarkably well intact. Of the 72 persons aboard the aircraft, 10 survived the accident.



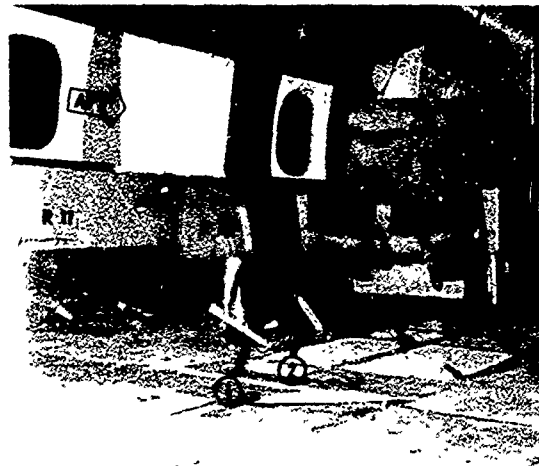
From the standpoint of crash survival, the tail section was of interest since only in this area were impact conditions of a possible survivable nature. The three side-facing occupants of the lounge survived, although one of them experienced seat belt attachment failure. One occupant of the only passenger seat that remained in place in the cabin - the aft-most seat on the right - is known to have survived. His seat belt held. The fate of the occupants of the other double seats in this intact cabin area is not exactly known. It is known, however, that at least seven (7) of them did not survive.

The seat failures were the result of inertia forces acting almost parallel to the longitudinal axis of the aircraft. Typical seat anchorage failures consisted



APPENDIX A

of pulled-out wall fittings and sheared-off leg plates. In that respect, this accident proved convincingly that the present occupant tie-down criteria are well below survivable human G tolerances and are no longer consistent with the apparent strength of modern fuselage structure.



Lack of reliable medical data, especially on the survivors, made it impossible to accurately determine the effect of occupant environment on impact survival. There are indications, however, that the integrated service trays were a potential source of head injuries while the aft beam of the seat frame undoubtedly caused numerous leg fractures. This confirms past accident experience showing that the full benefit of seat belt restraint can be realized only in combination with a non-injurious occupant environment.

Detailed findings from this accident are being combined with findings from other similar accidents and will be reported in a general analysis dealing with impact survival in transport accidents.

APPENDIX A

AERONCA ACCIDENT APACHE JUNCTION, ARIZONA 4 DECEMBER 1960

An Aeronca aircraft crashed shortly after take-off at approximately 5:15 P.M. on 4 December 1960 at Apache Junction, Arizona.

The aircraft took off from a small landing strip in the vicinity of Apache Junction, immediately executed a 180-degree turn, and buzzed the strip at an altitude of 5 to 6 feet. An abrupt pull-up was necessary to clear high tension



wires and at approximately 300 feet altitude the aircraft stalled. The nose was lowered but due to insufficient altitude complete recovery was impossible. Prior to striking the blacktop of a highway intersection, the aircraft struck a moving car, cutting two gashes

in the roof structure. Immediately thereafter the aircraft struck the blacktop with a high vertical force and moderate forward deceleration, demolishing the aircraft.

Both occupants were killed upon impact.

The detailed findings of this accident will be used in general crash survival studies of light fixed-wing aircraft.



LUSCOMBE ACCIDENT
GLENDALE, ARIZONA
6 DECEMBER 1960

A Luscombe aircraft crashed approximately 6 miles west of Glendale, Arizona at 12:45 P.M. on 6 December 1960.

The pilot, returning from a cross-country flight, buzzed his home and experienced a partial engine failure. The aircraft struck the ground with the left wing and left gear, bounced, and began cartwheeling. The aircraft again struck the ground on the nose after rotating 190 degrees, bounced again, and contacted the ground on the right side in the original flight path direction. The aircraft was demolished.



The pilot, lone occupant, sustained dangerous injuries.

The detailed findings of this accident will be used in crash survival studies involving light fixed-wing aircraft.

APPENDIX A

PIPER PA-18 ACCIDENT 40 MILES NORTH OF PHOENIX, ARIZONA 9 DECEMBER 1960

A Piper PA-18 (Super Cub) engaged in a message pick-up was damaged while attempting a landing on a rocky mountain road the afternoon of 9 December 1960 approximately 40 miles north of Phoenix, Arizona. The aircraft was assigned and operated by the Civil Air Patrol.

The aircraft was dispatched for an aerial message pick-up in conjunction with a Civil Defense maneuver. Due to an erroneous emergency signal from the ground party, an intermediate landing was attempted on rock strewn single lane road, the only suitable area in the mountainous terrain.



During the attempted landing, the aircraft bounced, became airborne a short distance, and then touched down again. During the second touchdown, the left landing gear struck a large rock causing the left gear to fail. This, in turn, caused the nose area to drop sufficiently to damage the propeller and the aircraft slid to a stop.

No injuries were sustained by the two occupants.

The detailed findings of this accident will be used in crash survival studies involving light fixed-wing aircraft.

PUBLICATIONS LIST

The following is a list of publications referenced in this report:

L-188
Lockheed Electra Accident
La Guardia Airport
New York City, New York
3 February 1959

U. S. Army U-1A
DeHavilland Otter Accident
Fort Carson, Colorado
16 June 1959

U. S. Army HU-1A
Bell Iroquois Helicopter Accident
East St. Louis, Illinois
21 October 1959

U. S. Army H-21C
Shawnee Helicopter Accident
Big Meadows, Virginia
2 December 1959

U. S. Army
AC-1 DeHavilland Caribou
Ft. Rucker, Alabama
21 January 1960

U. S. Army
YHC-1B Chinook Mock-up
Morton, Pennsylvania
27 January 1960

Crash Injury Bulletin
Improper Instruction in the Use of
Safety Belts in H-21 Helicopter Manual
March 1960

Cessna 182 Accident
Morristown, Arizona
21 March 1960

Cessna 182 Accident
Pica, Arizona
24 March 1960

U. S. Army
AO-1BF Mohawk Mock-up
Bethpage, Long Island, New York
31 March 1960

U. S. Army L-21A
Piper Super Cub Accident
Starkville, Mississippi
27 April 1960

U. S. Army YH-41
Cessna Helicopter Accident
Phoenix, Arizona
8 May 1960

Impact Survival in Rotary Wing
Military Aircraft - (Paper)
13 May 1960

Medical Officer's Role in the Crash
Injury Prevention Program - (Paper)
7-8 June 1960

U. S. Army HU-1A
Bell Iroquois Helicopter Accident
Fort Carson, Colorado
7 June 1960

U. S. Army H-13G
Bell Helicopter Accident
Fort Devens Army Airfield
Fort Devens, Massachusetts
1 July 1960

APPENDIX B

PUBLICATIONS LIST (Cont'd.)

U. S. Army HU-1D
Bell Iroquois Helicopter Mock-up
Fort Worth, Texas
8 July 1960

Stearman Accident
Phoenix, Arizona
10 July 1960

U. S. Army HU-1A
Bell Iroquois Helicopter Accident
Fort Bragg, North Carolina
20 August 1960

Crash Injury Bulletin
Part I - Attachment of Seat Belts in the
HU-1A Helicopter
Part II - Stowage of Equipment Under
Troop Seats
September 1960

The Mechanism of Aviation Crash
Injuries - (Paper)
18-23 September 1960

Summary Evaluation
U. S. Army HU-1A Bell Helicopter
Based on 3 Evaluations and 5 Accidents
October 1960

Lockheed Electra Accident
Logan Airport
Boston, Massachusetts
4 October 1960

Impact Survival in Air Transport
Accidents - (Paper)
14-18 November 1960

Aeronca Accident
Apache Junction, Arizona
4 December 1960

Luscombe Accident
Glendale, Arizona
6 December 1960

U. S. Army National Guard
H-23C Hiller Helicopter
Accident
Phoenix, Arizona
8 December 1960

Piper PA-18 Accident
40 miles north of Phoenix,
Arizona
9 December 1960

H-25 Helicopter Drop Test
Preliminary Report

H-25 Helicopter Drop Test
Technical Report